THESIS/
REPORTS
MONNING
E.C.

Analysis of human health risk of USDA Forest Service use of herbicides to control noxious weeds in the Northern Region

# ANALYSIS OF HUMAN HEALTH RISKS OF USDA FOREST SERVICE USE OF HERBICIDES TO CONTROL NOXIOUS WEEDS IN THE NORTHERN REGION

Prepared by

Edward C. Monnig
USDA Forest Service
Northern Region
Cooperative Forestry and Pest Management
P. O. Box 7669
Missoula, Montana 59807

February 1986

# ANALYSIS OF HUMAN HEALTH RISKS OF USDA FOREST SERVICE USE OF HERBICIDES TO CONTROL NOXIOUS WEEDS IN THE NORTHERN REGION

TABLE OF CONTENTS


| | Page |
|---|---|
| 1. INTRODUCTION | 1 |
| 1.1 Overview of Forest Service Noxious Weed Chemical Control Program | 1 |
| 1.2 Procedural Problems Associated with Herbicide Applications | 2 |
| 1.3 Affected Population | 2 |
| 1.4 Affected Population Exposure and Dose | 2 |
| 1.5 General Toxic Effects of Herbicide Exposure | 2 |
| 1.6 Comparisons of Dose and Effect Levels | 3 |
| 1.7 Carcinogenic and Mutagenic Effects | 3 |
| 1.8 Note on Data Sources | 3 |
| 1.9 Metric Usage, Scientific Notation and Other Issues | 4 |
| 2. RISK ANALYSIS | 5 |
| 2.1 DESCRIPTION OF THE FOREST SERVICE SPRAY PROGRAM AND THE MODEL PROJECTS | 5 |
| 2.1.1 Small, Open-Range/Forest, Model Project | 7 |
| 2.1.2 Mid-sized, Open-Range/Forest, Model Projects | 7 |
| 2.1.3 Large, Open-Range/Forest, Model Project | 9 |
| 2.1.4 Model Right-of-Way/Riparian Project | 9 |
| 2.2 ERRORS AND MISAPPLICATIONS ASSOCIATED WITH HERBICIDE SPRAY PROJECTS | 13 |
| 2.2.1 Error of Measurement During Manufacturing | 13 |
| 2.2.2 Errors of Measurement in the Field | 13 |
| 2.2.3 Excess Swath Overlap During Application | 13 |
| 2.2.4 Use of A Herbicide Not Scheduled for A Particular Area | 14 |
| 2.2.5 Treatment of an Area Not Scheduled for Treatment | 14 |

TABLE OF CONTENTS, cont.


| | Page |
|---|---|
| 2.3 AFFECTED POPULATIONS | 15 |
| 2.3.1 Small Open-Range/Forest Project: Affected Population | 15 |
| 2.3.2 Mid-sized Open-Range Projects: Affected Populations | 16 |
| 2.3.3 Large-sized Projects: Affected Populations | 16 |
| 2.3.4 Right-of-Way Projects: Affected Populations | 16 |
| 2.4 EXPOSURE LEVELS FOR AFFECTED POPULATIONS | 18 |
| 2.4.1 Introduction to Worker Exposure and Dose | 18 |
| 2.4.2 Introduction to General Public Exposure and Dose from Ground Spray Equipment | 23 |
| 2.4.3 Affected Population Doses from Small, Open-Range Projects | 27 |
| 2.4.3.1 Worker Doses, Small Projects | 27 |
| 2.4.3.2 General Population, Direct Dose from Drift | 29 |
| 2.4.3.3 General Population, Oral Doses | 30 |
| 2.4.3.4 General population, Reentry and Oral Doses | 31 |
| 2.4.4 Affected Population Doses from Mid-Sized, Open-Range Projects | 39 |
| 2.4.41 Worker Doses, Mid-sized Projects | 39 |
| 2.4.4.2 General Population, Direct Dose from Drift | 39 |
| 2.4.4.3 General Population, Oral Doses | 47 |
| 2.4.4.4 General Population, Reentry and Oral Doses | 47 |
| 2.4.5 Affected Population Doses from Large, Open-Range Projects | 47 |
| 2.4.5.1 Worker Doses, Large Projects | 47 |
| 2.4.5.2 General Population, Direct Dose from Drift | 47 |

TABLE OF CONTENTS, cont.


| | Page |
|---|---|
| 2.4.5.3 General Population, Oral Doses | 54 |
| 2.4.5.4 General Population, Reentry and Oral Doses | 54 |
| 2.4.6 Affected Population Exposure and Dose from Right-of-Way Projects | 54 |
| 2.4.6.1 Worker Doses | 54 |
| 2.4.6.2 General Population, Direct Dose from Drift | 56 |
| 2.4.6.3 General Population, Oral Dose, Beef and Vegetation | 57 |
| 2.4.6.4 General Population, Doses from Aquatic Contamination | 61 |
| 2.5 REVIEW OF GENERAL TOXICITY DATA FOR HERBICIDES | 64 |
| 2.5.1 Toxicity of Pesticide Formulations | 69 |
| 2.5.2 Toxicity of Herbicide Product Impurities | 69 |
| 2.5.2.1 Dioxins and Phenolics in 2,4-D | 69 |
| 2.5.2.2 Nitrosoamine Formation from Glyphosate | 72 |
| 2.6 DOSE/TOXICITY LEVEL COMPARISONS | 74 |
| 2.6.1 Discussion of ADI and NOEL Comparisons for the General Population Doses | 91 |
| 2.6.2 Discussion of ADI and NOEL Comparisons for Worker Doses | 92 |
| 2.7 PROBABILITIES OF IRREVERSIBLE IMPACTS | 96 |
| 2.7.1 Amitrole Mutagenesis Tests | 96 |
| 2.72. Atrazine Mutagenesis Tests | 98 |
| 2.7.3 2,4-D Mutagenesis Tests | 98 |
| 2.7.4 Dicamba Mutagenesis Tests | 98 |
| 2.7.5 Glyphosate Mutagenesis Tests | 98 |
| 2.7.6 Hexazinone Mutagenesis Tests | 99 |

Page

2.7.7 Picloram Mutagenesis Tests..... 99

2.7.8 Carcinogenic Potential of Herbicides..... 99

2.8 SYNERGISM/CUMULATIVE EFFECTS..... 125

3. ACCIDENT SCENARIOS..... 127

3.1 Background..... 127

3.2 Truck Spills..... 127

3.2.1 Probability of Occurrence..... 127

3.2.2 Worst-Case Truck Spill..... 130

3.2.3 Probability of a Worst-Case Truck Spill..... 134

3.3 Worst-Case Aircraft Spill..... 135

3.3.1 Probability of Occurrence..... 13

3.3.2 Worst-Case Aircraft Spill..... 137

3.3.3 Probability of Worst-Case Aerial Exposure..... 137

3.4 Other Accident Exposure Scenarios..... 138

REFERENCES..... 139

APPENDIX A..... A-1

APPENDIX B..... B-1

TABLE INDEX


Page

Table 2.1 Pesticide application rates..... 6

Table 2.2 Summary of 2,4-D dose data from Nash et al. (1982) and Lavy et al. (1982)..... 19

Table 2.3 Summary of worker dose data from Lavy et al. (1984)..... 19

Table 2.4 Worst-case worker dose factors..... 22

Table 2.5 Highest drift deposition levels collected on mylar sheets at specified distances from ground application spray projects (Yates et al. 1978)..... 24

Table 2.6 Drift deposition on vegetation at specified distances (from Yates et al. 1978)..... 25

Table 2.7 Application rates including mixing errors and swath overlap for open-range projects..... 28

Table 2.8 Worst-case worker dose levels from spraying small, open-range projects for 1 day (three projects per day)..... 29

Table 2.9 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with 2,4-D..... 32

Table 2.10 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with picloram or amitrole..... 33

Table 2.11 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with hexazinone..... 34

Table 2.12 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with glyphosate or dicamba..... 35

Table 2.13 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/picloram mixture..... 36

Table 2.14 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/dicamba mixture..... 37

Table 2.15 Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with atrazine..... 38

Table 2.16 Daily worker dose levels from spraying mid-sized, open-range projects..... 39

TABLE INDEX, cont.

Page

Table 2.17 Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with 2,4-D..... 40

Table 2.18 Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with picloram or amitrole..... 41

Table 2.19 Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with hexazinone..... 42

Table 2.20 Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with glyphosate or dicamba..... 43

Table 2.21 Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/picloram mixture..... 44

Table 2.22 Worst-case dose levels to visitors and residents in the vicinity of mid-sized, open-range project sprayed with a 2,4-D/dicamba mixture..... 45

Table 2.23 Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with atrazine..... 46

Table 2.24 Worst-case daily dose levels for backpack sprayers on large, open-range projects..... 48

Table 2.25 Worst-case daily dose levels for truck drivers and supervisors on large, open-range projects..... 49

Table 2.26 Worst-case dose levels to visitors and residents in the vicinity of a large, open-range project sprayed with 2,4-d, Picloram, or amitrole..... 50

Table 2.27 Worst-case dose levels to visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/picloram mixture..... 51

Table 2.28 Worst-case dose levels to visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/dicamba mixture..... 52

Table 2.29 Worst-case dose levels to visitors and residents in the vicinity of a large, open range project sprayed with dicamba, glyphosate, hexazinone, or atrazine..... 53

TABLE INDEX, cont.


Page

Table 2.30 Worst-case worker dose levels from spraying of right-of-way projects for 1 day..... 55

Table 2.31 Application rates including mixing errors and swath overlap for right-of-way projects..... 55

Table 2.32 Worst-case daily dose levels to visitors and residents in the vicinity of right-of-way projects sprayed with 2,4-D, picloram, amitrole, or dicamba..... 58

Table 2.33 Worst-case daily dose to residents in the vicinity of right-of-way projects sprayed with mixtures of 2,4-D/ picloram, or 2,4-D/dicamba..... 59

Table 2.34 Worst-case daily dose to visitors and residents in the vicinity of right-of-way projects sprayed with glyphosate, hexazinone, or atrazine..... 60

Table 2.35 Summary of references for herbicide concentrations in runoff..... 62

Table 2.36 Summary of acute and chronic toxicity thresholds based on test results with the most sensitive species..... 65

Table 2.37 Maximum fetotoxicity NOEL for most sensitive species and Acceptable Daily Intake (ADI) values..... 68

Table 2.38 Comparison of the acute oral toxicity of pesticide active ingredients and pesticide formulations..... 70

Table 2.39 Comparison of the acute dermal toxicity of pesticide active ingredients and pesticide formulations..... 71

Table 2.40 NOEL/dose comparisons for workers on small, open-range projects..... 75

Table 2.41 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with 2,4-D..... 75

Table 2.42 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with picloram..... 76

Table 2.43 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with dicamba..... 76

Table 2.44 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with glyphosate..... 77

Page

Table 2.45 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with 2,4-D/picloram..... 77

Table 2.46 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with 2,4-D/dicamba..... 78

Table 2.47 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with amitrole..... 78

Table 2.48 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with hexazinone..... 79

Table 2.49 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with atrazine..... 79

Table 2.50 NOEL/dose comparisons for workers on mid-sized, open-range projects..... 80

Table 2.51 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with 2,4-D..... 80

Table 2.52 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with picloram..... 81

Table 2.53 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with dicamba..... 81

Table 2.54 Worst-case NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinicty of a mid-sized, open-range project sprayed with glyphosate..... 82

Table 2.55 NOEL/dose and ADI/dose for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with 2,4-D/picloram..... 83

Table 2.56 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with 2,4-D/dicamba..... 83

Table 2.57 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with amitrole..... 8

TABLE INDEX, cont.


Page

Table 2.58 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with hexazinone..... 84

Table 2.59 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with atrazine..... 84

Table 2.60 NOEL/dose and ADI/dose comparisons for backpack sprayers on large, open-range projects..... 85

Table 2.61 NOEL/dose and ADI/dose comparisons for truck drivers and supervisors on large, open-range projects..... 85

Table 2.62 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with 2,4-D or picloram..... 86

Table 2.63 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with glyphosate or dicamba..... 86

Table 2.64 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with 2,4-D/picloram or 2,4-D/dicamba..... 87

Table 2.65 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with amitrole or atrazine..... 87

Table 2.66 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with hexazinone..... 88

Table 2.67 Dose comparisons for workers on right-of-way projects..... 88

Table 2.68 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with 2,4-D or picloram..... 89

Table 2.69 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with dicamba or glyphosate..... 89

Table 2.70 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with 2,4-D/picloram mixtures..... 90

Page

Table 2.71 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with 2,4-D/dicamba mixtures..... 90

Table 2.72 NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with amitrole, atrazine, or hexazinone..... 91

Table 2.73 NOEL/dose comparisons for backpack sprayers using worst-case estimates, high-dose estimates, and average-dose estimates..... 94

Table 2.74 A summary of the possible roles for selected short-term tests in chemical hazard assessment..... 97

Table 2.75 Cancer probabilities for workers spraying small, open-range projects for 1 day..... 104

Table 2.76 Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with 2,4-D.... 105

Table 2.77 Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with picloram..... 106

Table 2.78 Cancer probabilities for visitors and residents in the vicinity of a small,open-range project sprayed with glyphosate..... 107

Table 2.79 Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/picloram mixture..... 108

Table 2.80 Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/dicamba mixture..... 109

Table 2.81 Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with amitrole..... 110

Table 2.82 Daily cancer probabilities for workers from spraying mid-sized, open-range projects..... 110

Table 2.83 Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with 2,4-D..... 111

TABLE INDEX, cont.

Page

Table 2.84 Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with picloram..... 112

Table 2.85 Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with glyphosate..... 113

Table 2.86 Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/picloram mixture..... 114

Table 2.87 Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/dicamba mixture..... 115

Table 2.88 Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with amitrole..... 116

Table 2.89 Daily cancer probabilities for backpack sprayers on large, open-range projects..... 117

Table 2.90 Daily cancer probabilities for truck drivers and supervisors on large, open-range projects..... 117

Table 2.91 Cancer probabilities for visitors and residents in the vicinity of a large, open-range project sprayed with 2,4-D, picloram, or glyphosate..... 118

Table 2.92 Cancer probabilities for visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/picloram mixture..... 119

Table 2.93 Cancer probability for visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/dicamba mixture or amitrole..... 120

Table 2.94 Daily cancer probabilities for workers spraying riparian/ right-of-way projects..... 120

Table 2.95 Cancer probabilities for visitors and residents in the vicinity of riparian/right-of-way projects sprayed with 2,4-D, picloram, or glyphosate..... 121

Table 2.96 Cancer probabilities for visitors and residents in the vicinity of riparian/right-of-way projects sprayed with a 2,4-D/picloram mixture..... 122

Page

Table 2.97 Cancer probabilities for visitors and residents in the vicinity of riparian/right-of-way projects sprayed with a 2,4-D/dicamba mixture or amitrole..... 123

Table 2.98 Lifetime risk of death or cancer resulting from everyday activities..... 124

Table 3.1 Worst-case doses and cancer probabilities from dermal exposure from an aerial spill..... 138

# 1. INTRODUCTION

This document analyzes the risk to human health resulting from herbicide use to control noxious weeds such as knapweed and leafy spurge on USDA Forest Service land in Region 1 (Northern Region). These risk analyses determine what human exposures might occur as a result of Forest Service herbicide applications and the probability and extent of adverse health effects as a result of these exposures. As such, these analyses involve the following steps:

1. Identification of important elements in the herbicide application program including sizes of spray areas, locations of spray areas, herbicide application rates, and application methods.

2. Identification of the problems, misapplications, and accidents that are possible with herbicide spraying projects and a determination of the probabilities of these events.

3. Identification of the human population potentially affected by spray programs (population at risk).

4. Determination of the exposure and dosage of the affected populations taking into account various possible errors and accidents as well as unavoidable exposure intrinsic to the application process.

5. Review of the health effects data indicating the general toxic effects of the compounds of interest.

6. Comparison of dose levels (from Step 4) with toxic effect levels for which safety thresholds can be assumed (from Step 5).

7. Discussion and determination of the probability of irreversible effects (cancer and heritable mutations) for which absolute safety thresholds cannot be assumed for the population at risk.

Each of these steps will be discussed briefly in the introduction and in greater detail in the main body of the report. Sections 1.1 through 1.7 and Sections 2.1 through 2.7 correspond topically to the seven discussion areas.

## 1.1 Overview of Forest Service Noxious Weed Chemical Control Program

Based on a review of noxious weed control strategies, past application practices, budgetary projections, and weed infestation types and extent, the Forest Service anticipates a maximum proposed annual application of about 10,000 pounds of herbicide to control noxious weeds on about 10,000 acres of Region 1 National Forest land. This annual control program would involve up to 1,000 separate projects ranging in size from less than 1.0 acre to several hundred acres. The areas sprayed with herbicides would comprise 0.04 percent of the 24,800,000 acres of National Forest in Region 1 (northern Idaho, Montana, North Dakota and western South Dakota). Noxious weed projects in the past have primarily involved ground application of the herbicides 2,4-D, dicamba, and picloram.

Because the impact of individual projects is a primary concern, various model projects which represent segments of the entire program acreage for Region 1 are analyzed. The potential impacts of catastrophic accidents (e.g., large truck spills) are also analyzed.

## 1.2 Procedural Problems Associated with Herbicide Applications

There is associated with any human activity the probability of errors. Mixing errors and over-application can increase human exposure and are assumed in the model projects. In addition, the drift of herbicide spray is considered intrinsic to the application process even with the ground application methods used in these projects.

Determination of rate or probability of occurrence of errors and accidents is difficult. These calculations are based on past incidence reports where available, and, where necessary, application of probability functions based on the Poisson distribution in order to determine the upper limits of the accident rate. Mixing errors that over-concentrate field mixtures are assumed to occur to the point that increased herbicide consumption would be noticed.

## 1.3 Affected Population

Two populations are considered in this risk analysis. The first includes the group of operators, supervisors, and associated personnel directly involved in the application of herbicides. The second population includes the members of the population-at-large who could directly contact the herbicide in spray drift, spills, and on sprayed vegetation and indirectly contact the herbicide through the consumption of contaminated water, vegetation, fish, and grazing animals. Impacts on fish, wildlife, and nontarget plant species are considered in this human health risk analysis insofar as they affect human consumers.

## 1.4 Affected Population Exposure and Dose

The exposure rate and the doses to the affected population are based on several sources. Several studies have measured herbicide concentrations in pesticide workers and these findings are applied in this analysis. In some cases doses to the general population have been extrapolated from worker data in order to analyze worst-case impacts. In other cases dosage has been calculated based on maximum drift rates, dermal exposure and absorption rates, and food intake rates.

## 1.5 General Toxic Effects of Herbicide Exposure

The general toxic effects of each herbicide are reviewed in this document. The $LD_{50}$ values (lethal dose to 50 percent of a given population) for each chemical are reviewed to indicate the relative toxicity of these compounds. The "no observable effect levels" (NOEL) for chronic exposure to a chemical are reviewed. Both $LD_{50}$ and NOEL values are provided for the animal species most sensitive to each herbicide.

In addition, this document provides acceptable daily intake (ADI) values for the herbicides of interest as determined by EPA review of the toxicity data for these compounds in the herbicide use registration process. ADI's are based on NOEL values using safety factors of 100 or greater.

## 1.6 Comparisons of Dose and Effect Levels

The dose levels to maximum-exposed members of the affected population are compared to NOEL and ADI values for each of the herbicides of interest. This comparison indicates the possibility of adverse human health impacts from the maximum calculated doses.

## 1.7 Carcinogenic and Mutagenic Effects

A separate discussion of the carcinogenic and mutagenic potential of herbicide doses is provided in this analysis. As noted in Section 2.7, amitrole is a demonstrated animal carcinogen and has been designated a probable human carcinogen. Questions have been raised concerning the possible carcinogenicity of 2,4-D, picloram, glyphosate, and atrazine. This analysis assumes that a herbicide is a carcinogen if any animal test data indicate carcinogenic activity, no matter how weak. The probabilities of a human carcinogenic response from the maximum doses are calculated in Section 2.7. These calculations are based on the animal test data and use a very conservative predictive model that tends to overestimate incidence of cancer.

## 1.8 Note on Data Sources

A variety of data sources are used in this analysis. An important source is Forest Service Agriculture Handbook No. 633 (USDA 1984) which summarizes the extensive data on the human health effects and the environmental effects of 12 herbicides, including the herbicides of interest here. Handbook No. 633 can be inspected by contacting the pesticide coordinator at any Forest Supervisor Office for the National Forests in Region 1 or at the Regional Office in Missoula.

Although Handbook 633 (USDA 1984) summarizes human health and environmental effects data, it was beyond the scope of this handbook to critically evaluate the raw data upon which conclusions were reached in the studies reported. The credibility of this analysis of Forest Service activities required that additional efforts be made to insure the validity of data used in this analysis. All herbicide health effects data were cross checked against health effects data used in the EPA herbicide registration process. Because raw data used in support of the registration process is reviewed extensively by EPA, the health effects data were discussed with the EPA toxicologists responsible for each of the herbicides. The progress and implications of on-going studies were also reviewed with these toxicologists.

The validity of some data submitted to the EPA has been questioned because of falsified data provided by Industrial Bio-Test Laboratories (IBT) to support certain pesticide registrations. Glyphosate was the only herbicide in this analysis that had a substantial number of toxicity tests performed by IBT in support of registration. All of the IBT tests on glyphosate have either been replaced or judged unnecessary to support registration. No IBT data are used in this risk analysis.

Much of the general environmental fate data on these herbicides was collected by investigators at Universities, government agencies, contract laboratories, and industry laboratories. This data base is generally very extensive for the herbicides of interest. Review of raw data from these studies to select the most valid results would be impossible given the variety of sources. Instead,

in reviewing data on a particular effect of interest (e.g., post-spray concentrations in water), values were selected from the data pool that would maximize projected human health impacts.

Because it is unlikely that all the University, government agency, contract, and industry laboratories are conspiring to distort effects data, the errors or inaccuracies in the data base will tend to be random. Selection of data that maximize projected human impacts thus insures that any inaccurracies contained in the data used in this analysis err on the side of overestimating human health effects.

## 1.9 Metric Usage, Scientific Notation and Other Issues

This document attempts to analyze risk in as complete a fashion as possible with all assumptions clarified and intermediate steps and calculations explicity detailed. As such, this document must cover issues and utilize analytic methods and terminology that are unfamiliar to the general public. When a concept is first developed, the document explains the terminology and methodology in terms that the average person can understand. In addition, a glossary is provided in Appendix A which defines scientific terms used in this analysis.

Examples of all calculations are provided to allow the interested reader to track the devlopment of dose factors and conclusions concerning human health impact. The metric system is used throughout in these calculations for several reasons. First, most of the scientific literature cited in this analysis uses the metric system. Second, a primary goal of this analysis is the calculation of the human dose which is universally expressed in metric terms, typically as the milligrams of compound taken in by the person per kilogram of body weight (mg/kg). Since we start metric in the literature and will end up metric in the dose, we stay metric in supporting calculations.

Finally, the metric system is much easier to use and to remember once the initial resistance is overcome. To orient the reader, English equivalents to metric units are provided in parentheses in the text.

Appendix B explains the use of scientific notation which expresses very large or small numbers in powers of 10. Readers unfamiliar with the system should consult this appendix.

# 2. RISK ANALYSIS

## 2.1 DESCRIPTION OF THE FOREST SERVICE SPRAY PROGRAM AND THE MODEL PROJECTS

Four model projects provide the basis for determining the human health impacts of the Forest Service program to control noxious weeds in Region 1. These models are based on the scope and design of the Forest Service control program as discussed below.

The total amount of herbicide sprayed annually by the Forest Service in Region 1 will vary depending on the extent of noxious weed infestation, prognosis for other control techniques such as biological control, funding levels, and other factors. Regionwide spraying will typically involve 10,000 pounds or less herbicide active ingredient (a.i.). In 1985, a high spray year because of a special congressional appropriation to control noxious weeds on Federal land, less than 7,000 pounds of herbicide (a.i.) were sprayed. The net acreage sprayed will typically be less than 10,000 acres. Less than 9,000 acres were sprayed in 1985.

In 1985, the herbicide 2,4-D comprised approximately two-thirds of the herbicide used to control noxious weeds in Region 1. Picloram use was approximately 22 percent of the total and dicamba use was approximately 10 percent of the total. No glyphosate was used to control noxious weeds in 1985 and annual use of less than 50 pounds is expected in the future because of the nonselective nature of this herbicide.

Herbicides can be applied at various application rates typically expressed as pounds of active ingredient (a.i.) per acre (lb/ac) or kilograms per hectare (kg/ha). Application rates depend primarily on the species of weed being controlled, and to a lesser extent, on site-specific variables such as soil types. Table 2.1 provides application rates for various herbicides and mixtures of herbicides. These application rates will be used in the risk analysis with allowances for application errors discussed in Section 2.2.

In many cases, the prescribed application rates in Region 1 are lower than those provided in Table 2.1. For example, picloram provides 99 to 100 percent control of knapweed for several years when applied at only one-quarter pound per acre. The use of the application rates on Table 2.1 plus allowances for application errors will, in itself, overestimate potential impacts of many spray projects.

The definition of a spray project used in this analysis is somewhat arbitrary. Because the Forest Service strategy in many areas is to contain the spread of noxious weeds rather than chemically eradicate massive, firmly established populations, herbicide spraying is often directed toward scattered infestations. Thus, a 10-acre plot designated for spraying might only contain 5 one-quarter-acre areas of noxious weeds. Typically, each of these infested areas is sprayed individually with a portable spray applicator.

Table 2.1--Pesticide application rates.

| Pesticide[1] | Nominal application rate in kilograms/hectare (pounds/acre) |
|---|---|
| 2,4-D | 2.2 (2) |
| Dicamba | 1.1 (1) |
| Glyphosate | 1.1 (1) |
| Picloram | 1.1 (1) |
| 2,4-D/ Picloram[2] | 1.1 (1)<br>0.3 (0.25) |
| 2,4-D/ Dicamba[3] | 1.3 (1.2)<br>0.7 (0.6) |

[1] In addition to the herbicides whose use is expected in Region 1 noxious weed control programs, this document analyzes impacts of the use of amitrole, atrazine, and hexazinone at nominal application rates of 1.1 kg/ha (1.0 lb/acre). These herbicides have been used to control noxious weeds in other regions of the Forest Service.

[2] Applied as a tank mix of 1.0 part 2,4-D to 0.25 part picloram.

[3] Applied as a tank mix of 1.0 part 2,4-D to 0.5 part dicamba.

Obviously in large areas of spotty infestations, it becomes difficult to determine where one spraying project begins and one ends. For the purpose of tabulating and analyzing the data for this analysis, if two sprayed areas were further than one-half mile apart, they were considered separate projects. By this criterion, Forest Service would spray 500 to 1,000 projects per year in Region 1.

In discussing a project, a distinction is made between gross and net area. Net area is the area actually sprayed with herbicide. Gross area is the area inside the smallest perimeter incorporating all the project spray areas and includes both the sprayed and unsprayed area. The gross area can often be 10 times or more than the net area.

Spraying projects can be divided into one of the three following categories based on locational variables: open-range/forest, road right-of-way (ROW), and riparian projects. Open-range/forest projects involve areas of National Forest System land used for grazing or for other agricultural, commodity, or wildlife purposes. Road right-of-way projects involve spraying strips of land

immediately adjacent to roads traversing National Forest System land. Riparian projects involve spraying areas in which at least part of the herbicide is applied within 50 feet of flowing or standing water. Most herbicide spraying in riparian areas occurs with the spraying of road rights-of-way which often parallel stream channels. For this reason right-of-way and riparian location variables have been combined into one model project type.

The four worst-case model projects used in this risk analysis include three open range projects (small, mid-sized, and large), and a combination road right-of-way/riparian project. The critical elements of these projects are defined such that the apparent risk from these projects is greatly increased. The descriptions of these model projects will indicate these conservative assumptions.

Although no actual project will look exactly like any one of the models, the risks involved in any actual project will almost certainly be less than the risks determined in the model project category to which it would be assigned. Although these model projects include extreme assumptions that will overestimate the risk from most, if not all actual projects, the Forest Service cannot absolutely guarantee that every project in the future will have less risk than a corresponding model project. The environmental analysis of each project will determine whether the project represents higher risk to affected populations than that calculated in the generic analysis.

### 2.1.1 Small, Open-Range/Forest, Model Project

The small open range/forest model project is assumed to involve herbicide applications to approximately 0.4 hectare (1 acre) of noxious weeds spread over a 4 hectare (10-acre) plot. This plot is assumed to be located in a southeast quarter section of National Forest System land. As shown in Figure 2.1, the entire section (1 square mile or 640 acres) is assumed to be National Forest System land. The private section closest to the spray area is assumed to contain a residence with four inhabitants located approximately 200 meters (220 yards) from the spray project. In addition, the house and its inhabitants are assumed to be directly downwind of the spray project.

The assumption of land in private ownership close to a small project is very conservative, since National Forests typically comprise large unbroken expanses of Federal land with few or no private inholdings. In those areas where National Forest System and private lands are interspersed in a checkerboard fashion, the private holdings are most often commercial timberlands with no residential populations. In the case of the eastern Montana and North Dakota National Grasslands, the inholdings would comprise parts of large, sparsely populated ranches often involving as many as 10 to 20 sections (square miles) of land.

The noxious weed infestations are assumed to be sprayed by two individuals with backpack sprayers. One-quarter day is spent by each applicator on this spray project.

### 2.1.2 Mid-sized, Open-Range/Forest, Model Projects

The mid-sized open range/forest project is assumed to involve herbicide application to approximately 8 hectares (20 acres) of noxious weeds spread over a 40-hectare (100-acre) plot. As with the small project, the spray area is assumed to be located in the southeast corner of a section with a residence

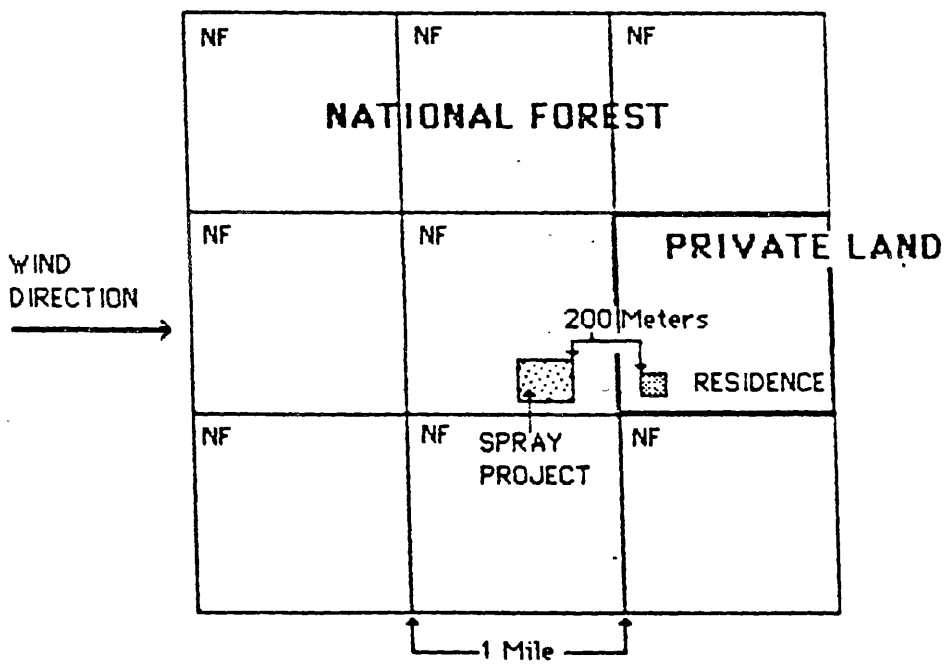



Figure 2.1.--Small and mid-sized open-range/forest model spray project.

located in an adjacent privately owned section. As with the smaller projects, the closest border of all mid-sized projects is assumed to be located within 200 meters upwind of the residence.

Spraying of this mid-sized spray project is assumed to be accomplished by two applicators with backpack sprayers. Each applicator spends 3 days on this project.

### 2.1.3 Large, Open-Range/Forest, Model Project

In a typical year, the National Forest System will spray relatively few areas with continuous extensive infestations of noxious weeds. This risk analysis assumes a large project of 200 hectares (500 acres). As indicated in Figure 2.2, the 200-hectare plot is assumed to be located on a 9-section plot of National Forest System land with a residence located 200 meters downwind.

The close proximity of a large spraying project to neighboring residences would be highly unusual. Such projects are typically located in the interior of large tracts of National Forest System land. The configuration of private residences and sprayed areas again presents a conservative basis for assessing risk of spray operations to the general public.

These large projects would typically be sprayed with vehicle-mounted spray equipment. Edges and areas of rough terrain may be sprayed with backpack units. Because worker exposure is higher with backpack sprayers, it is assumed that 40 hectares (100 acres) are sprayed with these spray units and the remainder with vehicle-mounted spray equipment.

### 2.1.4 Model Right-of-Way/Riparian Project

The right-of-way (ROW) model project is assumed to involve both sides of 8 kilometers or 5 miles of road with two residences located within 60 meters of either end of the spray zone (see Figure 2.3).

The number of residents hypothetically impacted by this model project is higher than that typically impacted by National Forest System projects since most National Forest System roads transect land that is wholly administered by the National Forest System and contains little or no human habitation.

A small stream with a flow rate of approximately 1 cubic foot per second (cfs) is assumed to parallel the road approximately 15 feet from the closest spray point. Immediately downstream of the spray area, the small stream is assumed to flow into a larger 15 cfs stream which is capable of supporting a fishery.

Noxious weeds typically exist in scattered patches in road rights-of-way. These infestations would be sprayed with backpack spray equipment or with hand-held hoses affixed to truck-mounted tanks. Less frequently the entire right-of-way is sprayed with a truck-mounted boom sprayer extending 3 meters off the side.

Occasionally a 6-meter roadside swath can be reached in one pass with a combination of spray nozzles mounted off the front bumper plus the 3-meter

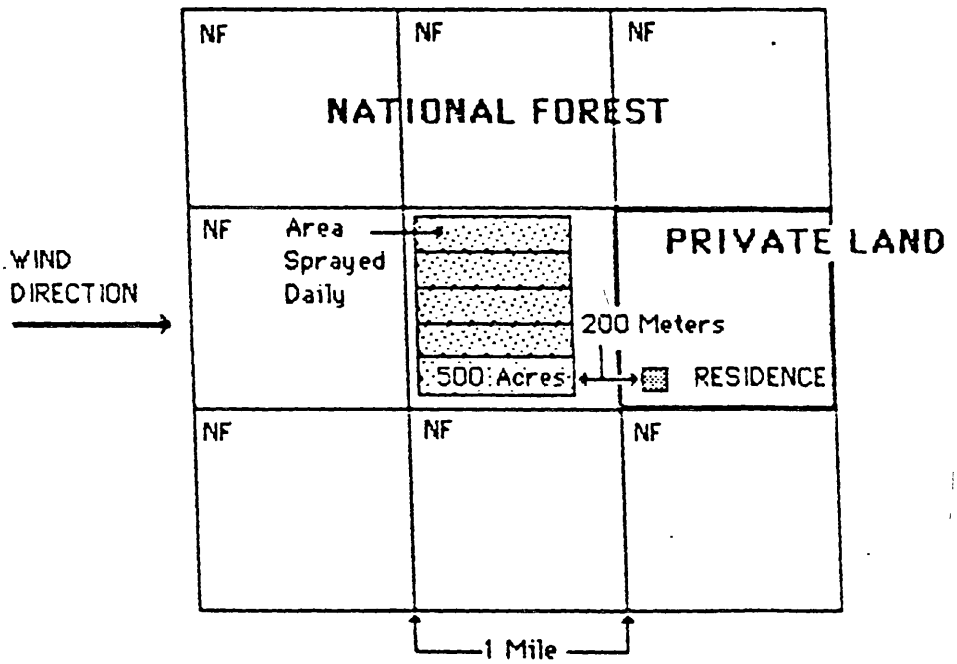
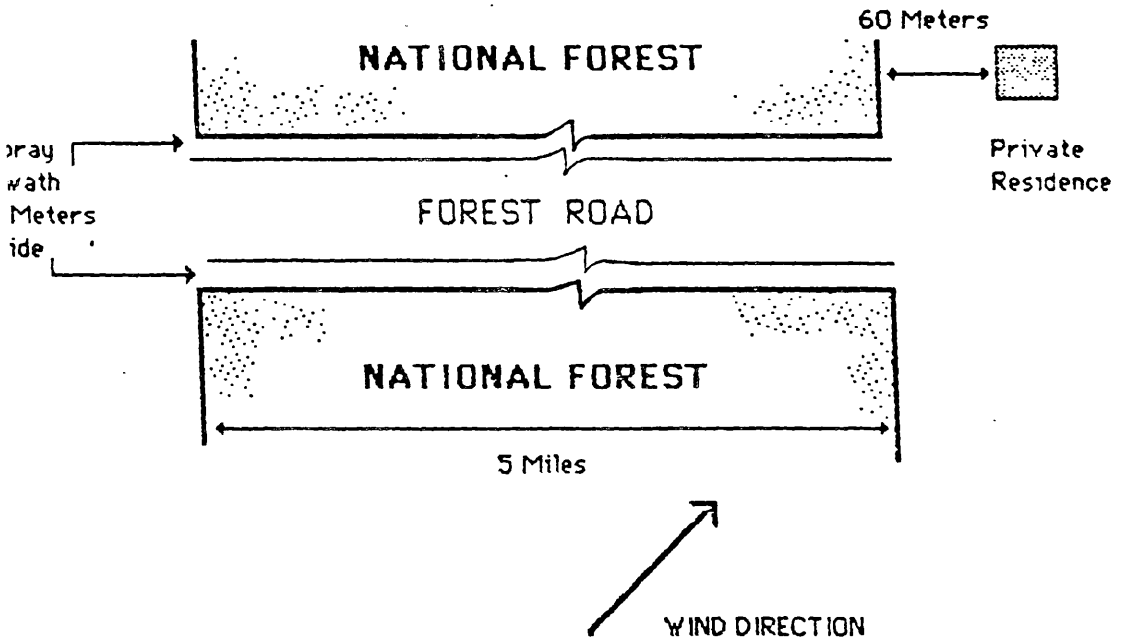



Figure 2.2.--Large, open-range/forest model spray project.




ure 2.3.--Right-of-way model spray project.

extension boom. On rough terrain, the truck must remain on the roadway. In this case, the 3 meters nearest the road would be covered by the extension boom. As an extreme case, this analysis will examine the impact of spraying the entire 6-meter swath on both sides of the road. Worker dose will also be analyzed on the assumption that an additional 1.3 hectares (3.3 acres) (net area) are sprayed with a hand-held nozzles or backpack sprayer.

## 2.2 ERRORS AND MISAPPLICATIONS ASSOCIATED WITH HERBICIDE SPRAY PROJECTS

This analysis assumes that the level of exposure and dose to both workers and the general public is directly related to the amount of herbicide applied per unit area. Deviations from the prescribed application rates can be affected by several factors including:

- Errors of measurement during manufacture and formulation
- Errors of measurement during field mixing
- Excessive swath overlap during application.

The extent and probability of these types of errors affecting application rates are discussed in this section. In addition, two other misapplications are discussed in this section.

- Use of a herbicide not scheduled for a particular area
- Treatment of an area not scheduled for treatment.

In addition to these operation errors, the impacts of major accidents such as truck spills into drinking water sources or onto land are discussed in Section 3.

### 2.2.1 Error of Measurement During Manufacturing

Pesticide manufacturers and formulators are required by EPA to maintain the concentration of pesticide in a product to within $\pm$ 4 percent of the stated concentration. Although the true concentration of various samples of a pesticide product would probably cluster about the labeled concentration, this risk analysis assumes that the actual concentration of the pesticide is always 4 percent greater than the labeled concentration. This assumption will increase the apparent public health and environmental impacts of herbicide spray programs.

### 2.2.2 Errors of Measurement in the Field

Most pesticide formulations require additional dilution for field applications. Errors can occur due to improper calibration of metering equipment, unskilled use of measuring instruments, etc. Again the actual diluted concentrations would probably cluster about the appropriate dilution rate. However, this risk analysis assumes that all pesticide mixtures for field applications are 10 percent higher concentration than prescribed. In addition, it was assumed that 1 percent of the backpack-applied pesticide solution was accidentally mixed at double strength. Both of these rates of mixing error are extremely high and their effects on pesticide composition or use rates would likely be noticed and improper dilution problems corrected.

### 2.2.3 Excess Swath Overlap During Application

It is assumed that 5 percent of the land sprayed on any individual project is sprayed twice due to swath overlap.

### 2.2.4 Use of A Herbicide Not Scheduled for A Particular Area

The USDA Forest Service in Region 1 anticipates using primarily three herbicides, 2,4-D, dicamba, and picloram, for chemical control of noxious weeds. In many cases, 2,4-D will be applied as a mixture with one of the other two herbicides. The herbicide use pattern at the National Forest or Ranger District level is even simpler and is often limited to one or two of the above herbicides depending on the weed infestations of the local area. Thus, the possibility of applying the wrong herbicide to a location is small to nonexistent.

More importantly, these herbicides do not differ significantly in most areas of human health and environmental impact. Where differences do exist, this risk analysis presumes the use of the herbicide resulting in the most significant impact in a particular location. For example, this analysis presumes that a 2,4-D/picloram mixture will be used in riparian habitats, although label directions and Forest Service policy prohibit the use of picloram in close proximity to water. These two herbicides are relatively mobile in soil/aquatic environments and weak evidence of carcinogenic potential for these herbicides exists.

It should be emphasized that assumptions concerning use patterns (e.g., 2,4-D/picloram by streamside) are made solely to establish extreme scenarios for this risk analysis and are not indicative of National Forest System pesticide-use policies.

### 2.2.5 Treatment of an Area Not Scheduled for Treatment

The model application projects outlined in Section 1 incorporate extreme assumptions to assess potential impacts. The application of herbicide to an area not scheduled for treatment would likely result in impacts less severe than those analyzed within the framework of the model projects.

The isolated location of most National Grasslands and National Forest land insures large buffer zones between spray areas and inhabited areas. The possibility of mistaken spraying of areas very close to human habitation is accounted for in the very conservative assumption that small, mid-sized, and large open range projects are within 200 meters of residences, and that right-of-way/riparian projects are within 60 meters of residences.

The effects of a major accidental spill of herbicide on sensitive areas is discussed in Section 3.

## 2.3 AFFECTED POPULATIONS

The population exposed to herbicides sprayed to control noxious weeds can be divided into two sets. The first set includes all those occupationally involved in the application of herbicides: truck drivers, mixer/loaders, handspray applicators, supervisors, and observers. The second set is composed of the general public subject to nonoccupational exposure. This group includes residents in the vicinity of sprayed areas, visitors to sprayed areas, and consumers of products potentially contaminated by herbicides.

### 2.3.1 Small Open-Range/Forest Project: Affected Population

As discussed in Section 2.1.1, it is projected to require two applicators with backpack sprayers approximately one-quarter day each to spray a small open range project. This pair of applicators is presumed to cover three small projects per day. No other workers or supervisors are assumed to be directly involved in the handling and application of these herbicides.

As discussed in Section 2.1.1, it is assumed that there is one residence with four inhabitants 200 meters directly downwind of each small, open-range project. The residents are assumed to include two adults (70 kg average weight), one adolescent (40 kg), and a 2-year-old (12 kg). These inhabitants are assumed to be outside during the entire spray event and thus exposed directly to spray drift.

The residents are also assumed to have a vegetable garden adjacent to their house and directly downwind of the spray zone. The residents are assumed to slaughter a steer for personal consumption immediately after it has grazed on herbicide-treated grass for a sufficient time to allow maximum accumulation of herbicide in body tissues. This beef will provide the sole source of meat for these inhabitants for 140 days.

As will be demonstrated in Section 2.4, none of these herbicides bioaccumulate to any extent in mammalian or aquatic species and they are rapidly eliminated after ingestion. Impacts on animals are quite transient and a secondary human dose of herbicides could only occur if the animals are slaughtered shortly after exposure.

In addition to inhabitants near the sprayed area, visitors are assumed on the sprayed area. National Forest System records indicate that the 10.1 million hectares (25 million acres) of Region 1 National Forest and Grasslands experience approximately 11.4 million visitor-days/year (a visitor day is considered to be 12 hours spent on forest land). Therefore, on average, Forest Service land in Region 1 receives about 1.25 visitor-day per hectare per year or one-half visitor-day per acre per year assuming a random distribution of forest visitors. Since most spraying will occur in areas with virtually no visitation at any time, the random distribution assumption will result in a high estimate of visitors to treated areas. Further, this risk analysis assumes that the half day of visitation to the small project occurs immediately after spraying.

National Forest System recreation records indicate that less than 1 percent of forest visitors gather edible wild foods. This risk analysis assumes that 1 percent of the visitors collect 0.5 pound of edibles from the treated areas. This is a very conservative estimate because prime foraging areas, such as huckleberry and other berry fields, have not been infested with noxious weeds.

### 2.3.2 Mid-sized Open-Range Projects: Affected Populations

As discussed in Section 2.1.2, spraying of a mid-sized project is assumed to require two applicators with backpack sprayers 3 days each on this project. No other workers or supervisors are assumed to handle or apply herbicides.

The assumptions regarding proximity and number of residents made for small projects are also made for mid-sized projects. Specifically a residence with four inhabitants is assumed on the adjacent section of land 200 meters directly downwind of the spray area. The assumptions made for small projects regarding garden location and consumption of beef by residents are also made for mid-sized projects.

As with the small projects, a visitor rate of 1.25 visitor-day/hectare (0.5 visitor-day/acre) is used for mid-sized projects. Visitors are assumed to be on-site shortly after spraying and 1 percent of visitors gather wild food from the site .

### 2.3.3 Large-sized Projects: Affected Populations

Large, continuous infestation areas of the type assumed in this analysis would be treated with vehicle-mounted spray rigs. Rough terrain, treatment block edges, and other hard to reach places would be sprayed with hand-held applicators. This risk analysis assumes that 80 percent of the project area would be sprayed with a vehicle-mounted spray equipment and that 20 percent of the project area would be sprayed with various hand-held application devices. The estimated portion sprayed by hand is probably high and increases apparent worker exposure from these projects because worker exposure is higher from hand applications than from vehicle-mounted spray applications. It is assumed to require 5 days of vehicle spraying by a truck driver who does his own mixing and loading. Six workers with backpack sprayers spray the remaining 20 percent (40 hectares) in a total of 30 worker-days. One supervisor directs the activities of these sprayers.

As described in Section 2.1.3, a residence is situated 200 meters downwind from the spray area. Similar assumptions regarding number of inhabitants, location of gardens, consumption of beef, etc., are made for the large projects as for the small and mid-sized projects.

Visitor use is assumed as in the other open-range projects.

### 2.3.4 Right-of-Way Projects: Affected Population

As discussed in Section 2.1.4, this analysis assumes that ROW projects are sprayed with a combination of boom sprayer and hand-held nozzle. Such an application method would require one truck driver and one hand-nozzle operator. Approximately 1 work day would be spent by these two people on this project.

The 16 kilometers (10 miles) of roadside in the model project are assumed to be equally distributed on either side of the road. One residence with four inhabitants is assumed located on either end of the spray zone approximately 60 meters (200 feet) downwind from the spray zone. Inhabitant ages and weights are as presented for small open-range projects in Section 2.3.1. Each resident

is assumed to be outside during the spraying episode. In addition, a 12-year old child (40 kg weight) is assumed to be attracted by the spray activity and to be 1 meter downwind of the spray zone during the spray operation. Two residents are also assumed to walk the length of the sprayed

The inhabitants in the vicinity of the spray area are also assumed to have a vegetable garden adjacent to their residence. The family also slaughters and consumes a steer which has grazed on drift-contaminated grass.
A fisherman is assumed to catch ten 8-ounce fish from the larger stream, downstream of the spray zone.

## 2.4 EXPOSURE LEVELS FOR AFFECTED POPULATIONS

This section determines the exposure and subsequent dose to workers involved in herbicide application as well as to the general public.

An important distinction should be made between exposure to pesticides and subsequent dosage. Exposure refers to the contact or potential contact between the chemical compound and the surface of the organism prior to incorporation of the chemical into cells or organs. The dose refers to the portion of the substance that is taken into the organism as a result of exposure. This distinction is made for several reasons. Exposure to herbicides during application is often a function of physical variables such as spray equipment, wind speed, height of application, and concentration of herbicide applied. Thus, the dermal exposure of a worker using a backpack sprayer will be similar whether he is spraying 2,4-D, dicamba, glyphosate, or any other herbicide as long as all other variables are held constant.

The dose or amount absorbed on exposure often depends on the chemical characteristics of the herbicide. For example, the dermal dose will be a function of the nature of the chemical and its interaction with cutaneous surfaces. The actual dose is pesticide specific although certain generalities on rate of absorption are possible and will be developed in this section.

As noted in Section 1, the herbicides 2,4-D, dicamba, and picloram have accounted for over 99 percent of the chemical use to control noxious weeds in Region 1. A small amount of glyphosate may also be used for noxious weed control. This analysis provides exposure and dosage data for these herbicides as well as the herbicides amitrole, atrazine, and hexazinone which have been used in other National Forest System Regions for control of noxious weeds.

### 2.4.1 Introduction to Worker Exposure and Dose

Exposure and dose factors for workers involved in applying herbicides of interest in this study are based on studies of workers applying 2,4-D, dichlorprop, and picloram (Lavy et al. 1982 and 1984 and Nash et al. 1982). These studies analyzed the urine of workers for the pesticides of interest as an indication of worker dose from all routes (dermal, inhalation, and oral). These studies also provided data on the amount of herbicide applied by these workers during the study period which allowed normalization of the data on a "per kilogram applied (or mixed)" basis. Other studies that do not provide such complete information are cited below as necessary to extend our understanding of worker dose.

Tables 2.2 and 2.3 summarize the results of the Lavy studies and the Nash study. For each worker category in Tables 2.2 and 2.3, two dose levels are provided. The first is the average dose of all workers studied in the category; the second is the highest dose to any worker studied in the category. This risk analysis places primary emphasis on the highest doses in each work category rather than the corresponding average value.

Table 2.2--Summary of 2,4-D dose data from Nash et al. (1982) and Lavy et al. (1982)[1]

| | Nash (1982) | | Lavy (1982) | |
|---|---|---|---|---|
| | Average | High | Average | High |
| Truck/tractor driver | $1.03 \times 10^{-3}$ | $7.6 \times 10^{-3}$ | | |
| Mixer/loader | $0.402 \times 10^{-3}$ | $1.04 \times 10^{-3}$ | | |
| Mixer/loader/driver | $0.85 \times 10^{-3}$ | $3.5 \times 10^{-3}$ | | |
| Pilot | | | $0.22 \times 10^{-3}$ | $0.625 \times 10^{-3}$ |
| Mechanic | | | $0.059 \times 10^{-3}$ | $0.147 \times 10^{-3}$ |
| Mixer/loader | | | $0.213 \times 10^{-3}$ | $0.403 \times 10^{-3}$ |
| Supervisor | | | $0.024 \times 10^{-3}$ | $0.075 \times 10^{-3}$ |
| Observer | | | $0.004 \times 10^{-3}$ | $0.013 \times 10^{-3}$ |

[1]All data are in milligrams of herbicide absorbed per kilogram of body weight per kilogram (a.i.) of herbicide mixed and/or applied.

Table 2.3--Summary of worker dose data from Lavy et al. (1984)[1]

| | Dichlorprop | | 2,4-D | | Picloram | |
|---|---|---|---|---|---|---|
| | Average | High | Average | High | Average | High |
| Backpack sprayers | 0.082 | 0.124 | 0.094 | 0.234 | | |
| Hypohatchet | | | 0.1637 | 0.3928 | 0.0185 | 0.16 |
| Injection bar | | | 0.026 | 0.101 | 0.00319 | 0.010 |
| Hack and squirt | | | 0.09 | 0.313 | 0.018 | 0.123 |

[1]All data are in milligrams of herbicide absorbed per kilogram of body weight per kilogram (a.i.) of herbicide mixed and/or applied.

In addition to the Lavy and Nash studies, Draper and Street (1982) measured via urinalysis the worker dose during applications of a mixture of 2,4-D and dicamba. This study alone does not indicate how dicamba dose relates to the application rate. However, because the workers applied a mixture of 2,4-D and dicamba, the study indicates that dicamba dose to workers will not exceed 2,4-D dose under similar work conditions. Thus, data on 2,4-D from the Lavy et al. and Nash et al. studies can be extrapolated to dicamba.

Several other herbicides of interest in this risk analysis are not included in studies by Lavy et al. and by Nash et al. In order to extrapolate from their findings, several factors should be reviewed. First, various aspects of the studies by Lavy et al. (1982 and 1984) and Nash et al. (1982) insure that their worker dose values are extreme estimates of possible worker dose in the noxious weed control program. All measurements cited in Tables 2.2 and 2.3 were taken on workers applying herbicides with little protective clothing. Worker apparel in these studies was often limited to short sleeve or sleeveless shirts, cotton pants, tennis shoes or nonrubberized boots, and baseball caps. Workers with backpack sprayers in the Lavy studies were spraying in brush fields 5 to 7 feet high and worker clothing was often saturated with a combination of dew, sweat, and herbicide by the end of the day. By contrast, most noxious weeds are 3 feet or less in height and spraying these weeds will likely result in less blow-back onto workers.

The dose levels measured in these studies are based on workers in large, multi-person crews. Thus, dose to a worker in these studies includes effects from his own activities as well as drift from other workers' activities. In the case of backpack sprayers, the incremental impact of other backpack sprayers is probably a very small portion of his overall dose.

Finally, to extrapolate from the findings of the studies by Lavy et al. (1982 and 1984) and by Nash et al. (1982), it is helpful to understand more completely the mechanisms involved in worker dose. Three exposure pathways account for all of a worker's dose: the dermal adsorption of herbicide drift impacting skin, inhalation of herbicide mist, and oral doses.

By measuring the quantities of herbicide impinging respirator filters, Lavy et al. (1982 and 1980) have demonstrated that the dose from inhalation is negligible (less than 1 percent) of the dose from other routes. Data presented on Table 2.3 also supports this conclusion. When picloram and 2,4-D are applied simultaneously in a mixture, the average worker dose of 2,4-D is five to nine times higher than the picloram dose when both doses are normalized for application amount. This difference is not surprising if we consider the data on the dermal absorption of 2,4-D and picloram. Nolan et al. (1984) have shown dermal absorption of picloram to be less than 1 percent whereas the measured dermal absorption rate for 2,4-D is approximately 6 percent (Feldman and Maibach 1974)

In contrast to the spread between the average worker dose values for 2,4-D and picloram, the difference between the highest recorded worker doses is not as great. Again this phenomenon can be explained when considering exposure mechanisms. At the higher dose levels recorded, it is likely that oral exposure is playing a more significant role. Unhygenic practices such as wiping mouths with contaminated hands or gloves could result in oral doses. Lavy (1984) reports that some workers would clear temporarily plugged hatchets by sucking or blowing on the feed line and spitting out the herbicide concentrate. This highly unrecommended practice would not be possible with backpack sprayers; however, it likely accounts for some of the high doses provided on Table 2.3 for other application methods.

Oral intakes of the types described above would be independent of the chemical characteristics of the herbicide and high oral intakes would tend to equalize doses from different herbicides. Thus, the highest worker doses which form the basis for this extrapolation tend to be less variable across pesticides.

To extrapolate the findings of the Lavy and the Nash studies with full confidence, it is important to quantify differences in dermal absorption rate since these differences will account for the major differences in worker dose. For example, based on the human dermal absorption tests with picloram, it can be predicted worker dose rates for picloram will be less than 2,4-D rates. Unfortunately dermal absorption rate data for humans for the herbicides amitrole, atrazine, dicamba, glyphosate, and hexazinone are not available. However, data from animal studies of the dermal absorption of these herbicides defines the outer limits of dermal absorption in humans.

Tests of glyphosate on monkeys have shown dermal absorption rates of 2 percent (Peterson 1983). Tests of amitrole on rats indicate that amitrole has a dermal penetration potential of 0.1 percent (USEPA 1985c). Tests of atrazine on rats have shown dermal absorption rates of 18 percent after 12 hours (Ballentine 1985). In these cases, the figures represent high estimates of dermal absorption in man based on an extensive review of the literature on dermal absorption including a review of interspecies comparative studies with a variety of compounds (Levin et al. 1984). Data reviewed indicate that dermal absorption rates in rats are typically several times higher than dermal absorption rates in man. Dermal absorption rates for monkeys more closely approximate those of man but once again overestimate rates in man. These species differences are likely a function of skin thickness, number of hair follicles, and other factors.

Based on a comparison of the dermal absorption rates for 2,4-D, amitrole, and glyphosate, the worker doses measured for 2,4-D can be used as conservative estimates of the worker doses for comparable applications of glyphosate and amitrole. Although worker doses from atrazine applications are likely to be comparable to or less than 2,4-D doses, the 2,4-D dose levels will be doubled to estimate atrazine dose because of the uncertainty in the atrazine dermal absorption rate for humans.

Quantitative dermal absorption rates for hexazinone are not available for any animal species. However, an estimate of dermal absorption rate of hexazinone can be made by comparing the acute dermal and the acute oral toxicity data for these herbicides. Since only a fraction of the chemical to which the animal is dermally exposed is absorbed into the body, dermal toxicity should be less than oral toxicity.

A review of mammalian test data for the compound hexazinone as contained in USDA Handbook 633 (USDA 1984) indicates that hexazinone has no lethal effects with dermal exposures as high as 6,000 mg/kg in rabbits. As discussed above, a comparison of dermal absorption of various chemicals by several mammalian species (rats, monkeys, rabbits, hairless pigs) shows the highest dermal absorption in rabbits (see Levin et al. 1984). Dermal exposure test results with hexazinone indicate that it is virtually impossible to induce a lethal response in mammals through dermal exposure.

Oral toxicity of hexazinone is also relatively low, although lethal doses are possible. An oral $LD_{50}$ (lethal dose to 50 percent of animals treated) of 860 mg/kg is indicated as a conservative value (USDA 1984). Because dermal exposures as high as 6,000 mg/kg are not lethal, it is obvious that relatively little hexazinone is absorbed through skin. A dermal absorption rate comparable to glyphosate or 2,4-D is very likely applicable for hexazinone.

However, because specific dermal absorption rate data for animals or humans are not available, the worker dose rates for 2,4-D are doubled to estimate conservatively the worker dose for hexazinone.

Table 2.4 provides the worker dose factors used in this analysis for herbicide applications. These dose factors are expressed as the milligrams of herbicide absorbed per kilogram of worker body weight per kilogram of herbicide applied. Therefore, in order to calculate worker dose, the quantity of herbicide applied daily must be calculated.

The assumption that dose is directly related to application amount is implicitly conservative. This analysis assumes, for example, that if a worker applies twice the herbicide in a day as applicators in Lavy's worker exposure study, then the applicator's dose is twice the baseline dose. This relationship is open to question since in Lavy's study, backpack sprayers were often saturated with herbicide mix although these workers generally sprayed less active ingredient in a day than assumed here. It is possible that they received a maximum dose and that spraying additional active ingredient in a work day would not effect dose. As an extreme example, the dose would be similar whether a 50-gallon barrel of a herbicide or a 100-gallon barrel of a herbicide were spilled over a worker because the quantity of herbicide that actually contacts the skin would be constant in either case. However, in the absence of experimental data indicating at what point worker dose levels off in typical application situations, it is conservatively assumed that dose follows a direct linear relation with application amount.

Table 2.4--Worst-case worker dose factors[1].

| | 2,4-D, Amitrole, Dicamba Picloram, Glyphosate | Atrazine, Hexazinone |
|---|---|---|
| Truck/tractor driver (including mixing and loading) | $7.6 \times 10^{-3}$ | $1.52 \times 10^{-2}$ |
| Mixer loader (aerial & ground) | $1.04 \times 10^{-3}$ | $2.08 \times 10^{-3}$ |
| Backpack sprayer | 0.234 | 0.468 |
| Pilot | $0.625 \times 10^{-3}$ | $1.25 \times 10^{-3}$ |
| Mechanic (aircraft) | $0.147 \times 10^{-3}$ | $0.29 \times 10^{-3}$ |
| Supervisor | $0.075 \times 10^{-3}$ | $0.150 \times 10^{-3}$ |
| Observer | $0.013 \times 10^{-3}$ | $0.026 \times 10^{-3}$ |

[1]All values are expressed in milligrams of herbicide absorbed per kilogram of body weight per kilogram of herbicide mixed and/or applied.

## 2.4.2 Introduction to General Public Exposure and Dose from Ground Spray Equipment

Drift of herbicide off-target during herbicide applications represents one of several ways in which persons in the vicinity of spray areas can be exposed to herbicides.

Several investigators (Yates et al. 1978, Maybank et al. 1977) have studied drift of herbicides from ground equipment as well as from aircraft. Yates and his coworkers have studied most completely the drift over relatively long distances (up to 1,000 meters) from ground-rig applications. Maybank and his coworkers provide more complete data concerning deposition on target and the deposition and drift of herbicide within short distances off target. Both types of data are useful in determining the impacts of spraying under the application scenarios outlined in Section 2.1.

In determining rates of drift from ground application, the highest rates of drift found in tests of ground equipment by Yates and his coworkers or by Maybank and his coworkers are assumed to occur at all times during ground application in Region 1. These drift rates very probably greatly overestimate drift from typical ground application since other tests have shown rates as much as 100 times lower. In addition, the drift rates used here were based on drift from tractor- or truck-mounted spray equipment employing high-pressure spray booms and spraying over 3 feet above the ground. Although drift from low-pressure backpack spray equipment is expected to be less than the rates extrapolated from vehicle-mounted equipment, in the absence of data on backpack sprayers, the drift rates from vehicles are applied to all ground equipment.

Table 2.5 presents data from Yates et al. (1978) on the deposition of drift onto downwind mylar sheets. Data for 10-meter-wide spray swaths are based on experimental results. Data from 100-meter-wide spray areas are calculated by Yates from the 10-meter results. Data are expressed as that fraction of an application rate that could be expected to be deposited at a specified distance from the spray site. For example, at 100 meters downwind from a 10-meter-wide strip sprayed at 1.3 kg/ha, the drift deposition would be 0.0156 mg/m$^2$ ($12 \times 10^{-5} \times 1.3$ kg/ha x 1 ha/10,000 m$^2$ x 1,000,000 mg/kg). Data from Table 2.5 are used to estimate drift deposition onto people in the drift zone.

Table 2.6 presents drift deposition data from Yates et al. (1978) for cereal wheat plants (4- to 5-leaf stage) located downwind of 10-meter-wide spray swaths (experimental data) or 100-meter swaths (calculated). Since this wheat had a very high surface-to-mass-ratio these data would indicate the highest concentrations on vegetables in gardens in the drift zone. Drift deposition at 200 meters from a 10-meter-wide swath sprayed at 1.3 kg/ha would be 0.031 mg/kg (0.024 mg-ha/kg$^2$ x 1.3 kg/ha). Dosage to humans is then based on assumptions regarding consumption rates.

The major difficulty in determining the drift at a given distance from a spray site is deciding the configuration of the actual spray area. As discussed in Section 2.1, the net spray area is often scattered over an area 10 times or greater than the area sprayed. As a worst-case assumption, it is assumed that the spray area is continuous with its nearest boundary at the distance to residences outlined in Section 2.1 (e.g., 200 meters between open-range projects and residences).

Drift data provided by Maybank et al. (1977) will be used to determine the impacts of several worst-case exposure scenarios. Because these data are more suited to site-specific treatment, they will be discussed fully in the section on exposure levels associated with riparian and right-of-way projects (Section 2.4.6.

Table 2.5--Highest drift deposition levels collected on mylar sheets at specified distances from ground application spray projects (Yates et al. 1978).

| Distance (meters) | Drift deposition from a 10-meter-wide spray swath[1] | Drift deposition from a 100-meter-wide spray swath[1] |
|---|---|---|
| 60 | $24 \times 10^{-5}$ | $9.5 \times 10^{-4}$ |
| 100 | $12 \times 10^{-5}$ | $6.4 \times 10^{-4}$ |
| 200 | $4.8 \times 10^{-5}$ | $3.6 \times 10^{-4}$ |
| 300 | $2.4 \times 10^{-5}$ | $2.4 \times 10^{-4}$ |
| 400 | $1.7 \times 10^{-5}$ | $1.7 \times 10^{-4}$ |
| 500 | $1.2 \times 10^{-5}$ | $1.2 \times 10^{-4}$ |
| 600 | $0.9 \times 10^{-5}$ | $1.0 \times 10^{-4}$ |
| 700 | $0.8 \times 10^{-5}$ | $0.8 \times 10^{-4}$ |
| 800 | $0.7 \times 10^{-5}$ | $0.7 \times 10^{-4}$ |
| 900 | $0.6 \times 10^{-5}$ | $0.6 \times 10^{-4}$ |
| 1,000 | $0.5 \times 10^{-5}$ | $0.5 \times 10^{-4}$ |
| 1,100 | - | $0.4 \times 10^{-4}$(2) |
| 1,200 | - | $0.4 \times 10^{-4}$ |
| 1,300 | - | $0.3 \times 10^{-4}$ |
| 1,400 | - | $0.3 \times 10^{-4}$ |
| 1,500 | - | $0.2 \times 10^{-4}$ |
| 1,600 | - | $0.2 \times 10^{-4}$ |

[1]Drift deposition at a given distance is expressed as the fractional portion of an application rate in mass/area (e.g., kg/ha, lbs/ac, $mg/m^2$, etc.).

[2]Values for 1,100 meters and beyond are extrapolated.

Table 2.6--Drift deposition on vegetation at specified distances (from Yates et al. 1978).

| Distance (meters) | Drift deposition from a 10-meter-wide spray swath[1] | Drift deposition from a 100-meter-wide spray swath[1] |
|---|---|---|
| 60 | 0.1 | 0.52 |
| 100 | 0.052 | 0.40 |
| 200 | 0.024 | 0.21 |
| 300 | 0.017 | 0.15 |
| 400 | 0.012 | 0.12 |
| 500 | 0.010 | 0.10 |
| 600 | 0.008 | 0.08 |
| 700 | 0.007 | 0.07 |
| 800 | 0.006 | 0.06 |
| 900 | 0.006 | 0.06 |
| 1,000 | 0.005 | 0.05[2] |
| 1,100 | - | 0.05[2] |
| 1,200 | - | 0.04 |
| 1,300 | - | 0.04 |
| 1,400 | - | 0.04 |
| 1,500 | - | 0.03 |
| 1,600 | - | 0.03 |

[1]Drift deposition is presented as milligrams of herbicide deposited per kilogram of vegetation per kilogram/hectare application rate ($mg\text{-}ha/kg^2$).

[2]Values for 1,100 meters and beyond are extrapolated.

Worst-case dosage to cattle foraging on herbicide-contaminated grass is calculated in this analysis. These dosage figures are compared to controlled feeding studies that measured herbicide intake and retention in cattle and other mammals. Secondary dosage to human consumers of herbicide-fed cattle can then be estimated based on assumptions regarding beef-consumption rates.

The dose to a 450 kilogram (1,000 pound) steer consuming 35 kilograms per day (75 pounds/day) of green weight forage that was directly sprayed with herbicide can be estimated as follows. Assuming 4,400 kilograms of green weight biomass per hectare of grazing land (4,000 pounds/acre) and assuming that herbicide lands only on forage, a 1.1 kilogram/hectare (1 pound/acre) treatment with herbicide would result in a herbicide concentration of 250 mg/kg on forage (1.1 kg/ha x hectare/4,400 kg x $10^6$ mg/kg). This value of 250 mg/kg is close to the maximum reported herbicide concentration of 240 mg/kg on range grass (normalized to a 1 lb/ac application rate) in a review by Hoerger and Kenaga (1972). Average values, including measurements of Montana range grass adjusted to a 1 lb/ac application rate, were 90 to 125 mg/kg. Assuming that a steer eats only forage with the maximum herbicide concentration, its daily dose would be 19.4 mg/kg (250 mg/kg x 35 kg/steer x steer/450 kg).

To estimate the maximum body burden (concentration) of herbicide in a steer consuming herbicide-treated grass, the literature on herbicide feeding studies was reviewed. Numerous studies with the pesticides of interest in this risk analysis indicate that after intake, these herbicides are rapidly excreted from mammalian systems. These studies will be reviewed briefly as a basis for making worst-case estimates of herbicide body burdens in cattle.

Khanna and Fang (1966) report 40 to 60 percent elimination of 60 to 100 mg doses of 2,4-D within 24 hours in rats. Cows and sheep fed up to 2,000 ppm 2,4-D in their diet for 28 days had average residue levels of less than 0.6 ppm in muscle, fat, and liver (Clark et al. 1975). At 300 ppm in feed, the 2,4-D residues in muscle were less than 0.05 mg/kg, 0.13 mg/kg in fat, and 0.11 mg/kg in liver. At all concentrations (300, 1,000, 2,000 ppm) the cattle ate less and refused food occasionally, presumably because of decreased palatability of food. Feed rates immediately returned to control levels in cattle withdrawn from dosing.

Dicamba feeding studies in cattle have shown that 60 percent of a dose (60 ppm, dietary) is excreted in 12 hours; that steady state, with herbicide intake matching excretion, is achieved in 2 to 3 days; that the maximum concentration in muscle tissue and fat is 0.03 mg/kg; and that liver concentrations are 0.3 ppm or less (Oehler and Ivie 1980).

Picloram is excreted very rapidly from mammalian systems. Nolan et al. (1984) found that more than 70 percent of a human oral dose of 5.0 mg/kg was recovered in urine in 6 hours. Ninety percent of the compound fed to dogs was excreted within 48 hours (Redemann, 1963, reported in National Research Council of Canada 1974; Fisher et al. 1965). Cattle fed from 1 to 1,600 mg/kg of picloram in feed for 4.5 to 8 weeks showed 0.05 to 0.5 mg/kg in muscle and fat, 0.12 to 2.0 mg/kg in liver and 2.0 to 18 mg/kg in kidneys (Kutschinski and Riley 1969). Kidneys contained less than 0.1 mg/kg if picloram was withdrawn from the diet 3 days before slaughter. At 400 ppm feed levels, muscle concentrations averaged 0.06 mg/kg and perirenal fat average 0.09 mg/kg picloram (Kutschinski and Riley 1969).

Glyphosate does not follow the typical urinary excretion pathway, primarily because this compound is absorbed only slowly across gastrointestinal membranes. Radiolabeled glyphosate fed in a single dose to rabbits was largely excreted in feces (greater than 80 percent) and to a lesser degree in urine (7 to 11 percent) within 5 days. A small amount (less than 1 percent) was expired as $CO_2$ or remained in the colon (U.S. Environmental Protection Agency data reported in Ghassemi et al. 1981 as cited in USDA 1984). Chickens were found to have a bioaccumulation factor as low as $10^{-4}$ for glyphosate in various tissues (Sacher 1978 as cited in USDA 1984). No storage of radiolabeled glyphosate was found in muscle or fat of bobwhite quail, although traces were found in liver and kidney tissues (U.S. Department of Agriculture 1981). Finally, chickens, cows, and pigs fed up to 75 ppm showed nondetectable residues in muscle and fat (less than 0.05 ppm) (Monsanto 1982).

Fang et al. (1964, 1966) fed radiolabeled amitrole to rats in concentrations of 1 to 200 mg/rat. From 79 to 89 percent of the total radioactivity administered was found in the urine and feces within 24 hours. Feces contained a small but variable amount of activity. Tissues absorbed material reaching a maximum in 1 hour, but the compound was excreted rapidly with a half-life averaging 4.2 hours in tissue. A half-life on this order is indicative of very little

bioaccumulation in muscle or fat. After a dose of 200 mg (about 500 mg/kg), amitrole levels in muscle tissues and in the stomach were nondetectable within 48 hours. Levels in blood were reduced over 99 percent within 48 hours and levels in liver were reduced almost 90 percent within 48 hours.

Hexazinone fed to goats at 5 ppm in diets showed residues of 0.01 ppm in muscle and fat (Schneider and Kaplan 1983 as cited in USDA 1984). Dairy cows administered 30 daily doses of up to 25 ppm in diet showed no hexazinone in muscle, fat, liver, or kidney at any dose tested (Schneider and Kaplan 1983).

Khan and Foster (1976) have shown no accumulation of atrazine in leg or breast muscle of chickens fed 100 ppm atrazine in diet for 7 days. However, abdominal fat contained 38.8 mg/kg atrazine.

Based on the feeding studies reviewed above, it is apparent that very little bioaccumulation of the herbicides of interest occurs in mammalian or avian species, particularly in edible muscle tissue. The only exception is the herbicide atrazine for which some evidence exists of accumulation in fat cells (though not in muscle tissue). This risk analysis assumes a maximum herbicide concentration of 0.1 mg/kg in cattle feeding on forage sprayed directly with herbicide except for the herbicide atrazine. For the herbicide atrazine, 1 mg/kg is used in this analysis. It is highly unlikely, of course, that cattle would graze only on herbicide-treated grasses, considering the scattered application of herbicides and the fact that noxious weeds (the spray target) are considered noxious because cattle and wildlife generally will not feed on them.

Because spraying for noxious weeds occurs in spring and early summer, the big game hunting season would not begin until a minimum of 2 months to as much as 7 months after the spraying. The small percentage of National Forest System land being sprayed, the wide-ranging habits of these animals, and the time intervals between spraying and the hunting season make impacts from eating wild game that may have grazed on herbicide-treated grass negligible by comparison to the doses from beef. Because this analysis assumes that beef that is maximally contaminated with herbicide is the sole source of meat for the residents, any substitution of another meat source will lessen the dose.

With these general introductory notes in hand, the dose potential for affected populations from each of the worst-case model projects will be determined.

### 2.4.3 Affected Population Doses from Small, Open-Range Projects

#### 2.4.3.1 Worker Doses, Small Projects

As discussed in Section 2.1.1, two workers with backpack sprayers will spray the small project in approximately one-quarter day. Under very ideal conditions, they could cover as many as three sites per day with allowances for travel and set up time.

In calculating the actual amount of herbicide applied, the 4 percent formulation error, the field mixing error, and 5 percent swath overlap were included. Table 2.7 lists the assumed application rates (including the increase from these mixing errors) for the herbicides used on small, open-range projects.

Table 2.7--Application rates including mixing errors and swath overlap for open-range projects.

| | Herbicide applied including minor mixing errors | | Herbicide applied assuming a major mixing error | |
|---|---|---|---|---|
| | Kg/ha | Lb/ac | Kg/ha | Lb/ac |
| 2,4-D | 2.6 | 2.4 | 3.2 | 2.9 |
| Picloram | 1.3 | 1.2 | 1.6 | 1.43 |
| Dicamba | 1.3 | 1.2 | 1.6 | 1.43 |
| 2,4-D/ | 1.3 | 1.2 | 1.6 | 1.43 |
| Picloram | 0.36 | 0.3 | 0.43 | 0.4 |
| 2,4-D/ | 1.6 | 1.44 | 2.0 | 1.8 |
| Dicamba | 0.8 | 0.7 | 1.0 | 0.9 |
| Glyphosate | 1.3 | 1.2 | 1.6 | 1.43 |
| Amitrole | 1.3 | 1.2 | 1.6 | 1.43 |
| Atrazine | 1.3 | 1.2 | 1.6 | 1.43 |
| Hexazinone | 1.3 | 1.2 | 1.6 | 1.43 |

To arrive at the assumed application rate involving minor mixing errors, the nominal rate (e.g., 1.1 kilogram/hectare or 1.0 pound a.i./acre) was multiplied by the assumed formulation error of 4 percent (e.g., 1.1 kg/ha x 1.04). The result was then multiplied by the assumed 10 percent mixing error (e.g., 1.14 kg/ha x 1.1). The result was then multiplied by assumed double swath rate of 5 percent (1.25 kg/ha x 1.05) for a final assumed application rate of 1.3 kg/ha (1.2 lb/ac).

In calculating the effect of double-strength mixing on application rates, it was assumed that 28 gallons of herbicide mix are applied per acre in eight batches of 3.5 gallons each. It is assumed that two batches are double-mixed per acre (which is equivalent to 25 percent of the batches being double-mixed). To calculate the actual amount applied, it was necessary to take a weighted average of 25 percent of the batches mixed at double strength (including also formulation error and swath overlap) and 75 percent of the batches with minor mixing error. The resulting application rate from a nominal 1.1 kg/ha rate is 1.6 kg/ha (0.25 (1.1 kg/ha x 1.04 x 2 x 1.05) + 0.75 (1.1 kg/ha x 1.04 x 1.1 x 1.05)).

Table 2.7 also provides application rates for amitrole, atrazine, and hexazinone based on a nominal rate of 1.1 kilogram/hectare (1 pound/acre). These herbicides have not been used in Region 1 for control of noxious weeds although they have been used in other Regions. Dose figures for workers and the general public are based on these assumed application rates and would require adjustment in the event of different application rates.

Table 2.8 presents worker dose for 1 day of spraying on the assumption that three projects are sprayed by two workers in a day. The worker exposure from spraying with minor mixing errors was calculated by multiplying the assumed application rate per net hectare (from Table 2.7) by the net hectares sprayed per worker per day (0.6 hectares or 1.5 acres) and multiplying this result by the backpack sprayer dose factor of 0.234 mg/kg/kg for 2,4-D, picloram, dicamba, glyphosate, or amitrole or 0.468 mg/kg/kg for atrazine or hexazinone (see Table 2.4).

Table 2.8--Worst-case worker dose levels from spraying small, open-range projects for 1 day (three projects per day).

| | Dose in mg/kg/day assuming minor mixing errors | Dose in mg/kg/day assuming major mixing error on 1 acre |
|---|---|---|
| 2,4-D | 0.37 | 0.42 |
| Picloram | 0.18 | 0.21 |
| Dicamba | 0.18 | 0.21 |
| 2,4-D/ | 0.18 | 0.21 |
| Picloram | 0.05 | 0.06 |
| 2,4-D/ | 0.22 | 0.26 |
| Dicamba | 0.11 | 0.13 |
| Glyphosate | 0.18 | 0.21 |
| Amitrole | 0.18 | 0.21 |
| Atrazine | 0.37 | 0.42 |
| Hexazinone | 0.37 | 0.42 |

In calculating worker dose from major mixing errors, it was assumed that two of twelve batches needed to spray 0.6 hectares (1.5 acres) in a day was mixed double strength by one worker. In effect, in 1 day this worker is assumed to be exposed to applications on 0.1 hectare sprayed with major mixing errors and 0.5 hectare sprayed with minor mixing errors. Worker dose from picloram sprayed for 1 day including major mixing errors is calculated to be 0.21 mg/kg ((0.1 ha x 1.1 kg/ha x 1.04 x 2 x 1.05 x 0.234 mg/kg/kg) + (0.5 ha x 1.1 kg/ha x 1.04 x 1.1 x 1.05 x 0.234 mg/kg/kg)).

2.4.3.2 General Population, Direct Dose from Drift

The possible dose to the general population must be calculated based on several possible exposure pathways. For small, open-range projects, these pathways include direct doses from drift, consumption of drift-contaminated vegetables, consumption of beef fed on herbicide-treated grasslands, dermal absorption from contact with spray-treated vegetation, and the consumption of herbicide-contaminated wild foods.

In order to calculate drift from a small, open-range project, it was assumed that the 0.4 hectare (1 acre) spray zone was a continuous area of dimension 100 meters by 40 meters. The orientation of this area is assumed to be such that the wind travels along the 100-meter length of the spray zone and the residence is 200 meters directly downwind. From Table 2.5 the drift factor for a 200-meter distance from a 100-meter-wide strip is $3.6 \times 10^{-4}$. Drift deposition from a 1.3 kg/ha (1.2 lb/acre) treatment would be 0.047 mg/$m^2$ (1.3 kg/ha x 1,000,000 mg/kg x ha/10,000$m^2$ x $3.6 \times 10^{-4}$).

Dermal absorption of drift by neighboring residents was calculated on the assumption that all residents were outside their residence during the entire spray episode. Adult skin surface area is assumed to be 1.7 $m^2$ (18.3 $feet^2$) of which 0.37$m^2$ (4 $feet^2$) is directly exposed (face, neck, "V" of chest, forearms, hands, and legs below knees). An adolescent resident is assumed to have 1.2 $m^2$ (13 $feet^2$) of skin of which 0.27 $m^2$ (3 $feet^2$) are exposed. An infant is assumed to have 0.45 $m^2$ (4.8 $feet^2$) of skin, of which 0.15 $m^2$ (1.6 $feet^2$) are exposed. All exposed skin is assumed to be directly in the drift pathway and contacted by drift (an extreme assumption).

Dermal absorption rate is assumed to be 1 percent for picloram and amitrole; 10 percent for glyphosate, dicamba, and 2,4-D; and 20 percent for atrazine and hexazinone. On this basis, the dose to a 70 kg adult from a 1.3 kg/ha application of picloram would be $2.5 \times 10^{-6}$ mg/kg (0.047 mg/$m^2$ x 0.37 $m^2$/adult x adult/70 kg x 0.01).

2.4.3.3 General Population, Oral Doses

Oral dose from consumption of a steer that fed directly on herbicide-treated grass was calculated as follows. The steer was assumed to be slaughtered at the point at which herbicide body burden is at its maximum. As demonstrated in Section 2.4.2, with the possible exception of atrazine, maximum body burden would not exceed 0.1 mg/kg and is very likely much less for the herbicides of interest. Assuming the steer had a dressed weight of 200 kilograms (440 pounds), that the herbicide concentration in edible parts averages 0.1 mg/kg (1.0 mg/kg for atrazine), that each adult consumes 0.5 kilograms (1.1 pounds) of beef per day, each adolescent consumes 0.3 kilograms (0.66 pounds) of beef per day, and each infant consumes 0.1 kilograms (3.5 oz) of beef per day, and that the herbicide in beef does not degrade with time or cooking, the daily oral dose of herbicide for a 70 kg adult would be $7.1 \times 10^{-4}$ mg/kg (0.5 kg/adult x adult/70 kg x 0.1 mg/kg). The steer would last this family of four about 140 days at these consumption rates.

Oral doses from eating drift-contaminated vegetables are calculated from measurements by Yates et al. (1978) of drift deposition on wheat seedlings as discussed in Section 2.4.2. Because wheat would typically have a much higher surface to mass ratio than garden vegetables, measurements by Yates et al. (1978) will serve as a worst-case estimate. Once again assuming a 100-meter by 40-meter plot, the drift deposition at 200 meters distance would be 0.21 mg/kg on vegetation for each kilogram of herbicide applied per hectare (from Table 2.6). For a 1.3 kg/ha application, the deposition would be 0.27 mg/kg (1.3 kg/ha x 0.21 mg-ha/$kg^2$).

Adults were assumed to consume 0.23 kilogram (8 ounces) of vegetables from the garden daily. Adolescents were assumed to consume 0.13 kilogram (5 ounces) of vegetables per day. Infants are assumed to consume 0.05 kilogram (2 ounces)

of vegetables daily. Assuming, as a worst case, that no herbicide was lost in washing or cooking, the dose to a 70 kg adult would be $8.9 \times 10^{-4}$ mg/kg (0.27 mg/kg x 0.23 kg/adult x adult/70 kg).

It is assumed that herbicide concentrations do not diminish over a 2-week period during which residents continue to consume vegetables. In fact, a combination of washing vegetables, irrigation and/or rain, photochemical degradation, and new growth will greatly reduce intake of herbicides below initial levels.

2.4.3.4 General Population, Reentry and Oral Doses

Several studies of herbicide residue in spray areas indicate that the herbicide exposure to persons reentering a spray area, after spraying has been completed, will be very small. Lavy et al. (1980) reported that individuals who walked through an acre sprayed 2 hours earlier with 2,4,5-T had no detectable dislodgable residue levels on patches which represented dermal exposure to skin and clothing. Also, Thompson et al. (1983) found that only 5 percent of 2,4-D applied to grasses could be removed by mechanical wiping immediately after spraying 1 to 2 lb a.i/acre. These residues dropped to less than 1 percent by 5 days after application. These data indicate that the exposure to herbicides from contacting treated foliage would be extremely small.

As a worst-case estimate of dose to a visitor to a spray site, the highest dose levels measured in a spray project supervisor who had spent a day on-site during spray application will be used. As shown on Table 2.4, the worst-case supervisor dose factor for 2,4-D, amitrole, dicamba, picloram, and glyphosate is $0.075 \times 10^{-3}$ mg/kg per kilogram of herbicide applied and for atrazine and hexazinone is $0.150 \times 10^{-3}$ mg/kg per kilogram of herbicide applied. Picloram dose would be $3.9 \times 10^{-5}$ (1.3 kg/ha x 0.4 ha x $0.075 \times 10^{-3}$ mg/kg/kg).

The dose to a forest visitor who collects and eats 0.23 kilogram (0.5 pound) of wild fruit from the spray site shortly after spraying is also provided. Based on reviews by Norris (1981) and Hoerger and Kenaga (1972) the upper concentration limit on fruit would be about 7 mg/kg for each pound of herbicide applied per acre, or about 6.5 mg/kg for each kilogram of herbicide applied per hectare. The dose to a 70 kilogram person eating wild fruit from a site sprayed at 1.3 kg/ha would be 0.028 mg/kg (1.3 kg/ha x 6.5 mg-ha/kg$^2$ x 0.23 kg/person x person/70 kg).

The chances of picking and consuming one-half pound of wild foods exclusively from noxious weed sites that have been directly sprayed with herbicides are extremely small. Even smaller is the probability of a person picking and consuming wild foods from an area that has been mistakenly sprayed with a double-strength batch of herbicide mixture. The odor and taste of the sprayed vegetation alone would alert the person to contamination. For example, at concentrations above 5 mg/kg on food, both picloram and 2,4-D impart a bitter taste to food, thus limiting exposure.

Tables 2.9 through 2.15 provide general population dose levels from the spraying of each herbicide or mixture of herbicides of interest on small projects.

Table 2.9--Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with 2,4-D.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $5.0 \times 10^{-5}$ | $6.2 \times 10^{-5}$ |
| Adolescent dermal dose | $6.4 \times 10^{-5}$ | $7.8 \times 10^{-5}$ |
| Infant dermal dose | $1.2 \times 10^{-4}$ | $1.5 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.8 \times 10^{-3}$ | $2.3 \times 10^{-3}$ |
| Infant oral dose (veg) | $2.2 \times 10^{-3}$ | $2.7 \times 10^{-3}$ |
| Visitor re-entry to spray site | $7.8 \times 10^{-5}$ | $9.6 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $5.6 \times 10^{-2}$ | $6.8 \times 10^{-2}$ |

Table 2.10--Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with picloram or amitrole.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $2.5 \times 10^{-6}$ | $3.2 \times 10^{-6}$ |
| Adolescent dermal dose | $3.2 \times 10^{-6}$ | $3.9 \times 10^{-6}$ |
| Infant dermal dose | $5.9 \times 10^{-6}$ | $7.4 \times 10^{-6}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $8.9 \times 10^{-4}$ | $1.1 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.1 \times 10^{-3}$ | $1.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $3.9 \times 10^{-5}$ | $4.8 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

Table 2.11--Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with hexazinone.

| | Dose including minor mixing errors (mg/kg/day) | Dose including major mixing errors (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $5.0 \times 10^{-5}$ | $6.3 \times 10^{-5}$ |
| Adolescent dermal dose | $6.4 \times 10^{-5}$ | $7.8 \times 10^{-5}$ |
| Infant dermal dose | $1.2 \times 10^{-4}$ | $1.5 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $8.9 \times 10^{-4}$ | $1.1 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.1 \times 10^{-3}$ | $1.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $7.8 \times 10^{-5}$ | $9.6 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

Table 2.12--Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with glyphosate or dicamba.

| | Dose including minor mixing errors (mg/kg/day) | Dose including major mixing errors (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $2.5 \times 10^{-5}$ | $3.2 \times 10^{-5}$ |
| Adolescent dermal dose | $3.2 \times 10^{-5}$ | $3.9 \times 10^{-5}$ |
| Infant dermal dose | $5.9 \times 10^{-5}$ | $7.5 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $8.9 \times 10^{-4}$ | $1.1 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.1 \times 10^{-3}$ | $1.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $3.9 \times 10^{-5}$ | $4.8 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

Table 2.13--Worst-case dose levels to visitors and residents in the the vicinity of a small, open-range project sprayed with a 2,4-D/picloram mixture.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $2.5 \times 10^{-5}$<br>$6.2 \times 10^{-7}$ | $3.2 \times 10^{-5}$<br>$8.0 \times 10^{-7}$ |
| Adolescent dermal dose | $3.2 \times 10^{-5}$<br>$8.0 \times 10^{-7}$ | $3.9 \times 10^{-5}$<br>$1.0 \times 10^{-6}$ |
| Infant dermal dose | $5.9 \times 10^{-5}$<br>$1.5 \times 10^{-6}$ | $7.5 \times 10^{-5}$<br>$1.9 \times 10^{-6}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $8.9 \times 10^{-4}$<br>$2.2 \times 10^{-4}$ | $1.1 \times 10^{-3}$<br>$2.7 \times 10^{-4}$ |
| Infant oral dose (veg) | $1.1 \times 10^{-3}$<br>$2.7 \times 10^{-4}$ | $1.4 \times 10^{-3}$<br>$3.5 \times 10^{-4}$ |
| Visitor re-entry to spray site | $3.9 \times 10^{-5}$<br>$1.0 \times 10^{-5}$ | $4.8 \times 10^{-5}$<br>$1.2 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$<br>$7.0 \times 10^{-3}$ | $3.4 \times 10^{-2}$<br>$8.5 \times 10^{-3}$ |

Table 2.14--Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/dicamba mixture.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $3.0 \times 10^{-5}$<br>$1.5 \times 10^{-5}$ | $3.8 \times 10^{-5}$<br>$1.9 \times 10^{-5}$ |
| Adolescent dermal dose | $3.9 \times 10^{-5}$<br>$1.9 \times 10^{-5}$ | $4.9 \times 10^{-5}$<br>$2.4 \times 10^{-5}$ |
| Infant dermal dose | $7.5 \times 10^{-5}$<br>$3.8 \times 10^{-5}$ | $9.4 \times 10^{-5}$<br>$4.7 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.1 \times 10^{-3}$<br>$5.3 \times 10^{-4}$ | $1.3 \times 10^{-3}$<br>$6.3 \times 10^{-4}$ |
| Infant oral dose (veg) | $1.4 \times 10^{-3}$<br>$7.0 \times 10^{-4}$ | $1.8 \times 10^{-3}$<br>$8.8 \times 10^{-4}$ |
| Visitor re-entry to spray site | $4.8 \times 10^{-5}$<br>$2.4 \times 10^{-5}$ | $6.0 \times 10^{-5}$<br>$3.0 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $3.4 \times 10^{-2}$<br>$1.7 \times 10^{-2}$ | $4.2 \times 10^{-2}$<br>$2.1 \times 10^{-2}$ |

Table 2.15--Worst-case dose levels to visitors and residents in the vicinity of a small, open-range project sprayed with atrazine.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $5.0 \times 10^{-5}$ | $6.3 \times 10^{-5}$ |
| Adolescent dermal dose | $6.4 \times 10^{-5}$ | $7.8 \times 10^{-5}$ |
| Infant dermal dose | $1.2 \times 10^{4}$ | $1.5 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-3}$ | $7.1 \times 10^{-3}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-3}$ | $8.3 \times 10^{-3}$ |
| Adult/adolescent oral dose (veg) | $8.9 \times 10^{-4}$ | $1.1 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.1 \times 10^{-3}$ | $1.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $7.8 \times 10^{-5}$ | $9.6 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

## 2.4.4 Affected Population Doses from Mid-Sized Open-Range Projects

### 2.4.4.1 Worker Doses, Mid-sized Projects

The dose to workers and the general population from mid-sized, open-range projects is calculated using the same basic methods as discussed for small projects.

As discussed in Section 2.3.2, it is assumed that two applicators with backpack sprayers spend 3 days each on this project. Thus, each applicator would spray approximately 1.3 net hectares (3.3 net acres) per day. Worker dose was again calculated by multiplying the kilograms of herbicide applied by the dose factor of 0.234 mg/kg/kg for 2,4-D, amitrole, dicamba, picloram, or glyphosate applied or 0.468 mg/kg/kg for atrazine or hexazinone. Table 2.16 provides these daily dose factors for workers. The major mixing error scenario assumes that one worker sprays 0.1 hectare (0.25 acre) with two batches of double-strength mixture. For a major mixing error involving picloram sprayed at a nominal rate of 1.1 kg/ha, the worker dose would be 0.43 mg/kg ((0.1 ha x 1.1 kg/ha x 1.04 x 2 x 1.05 x 0.234 mg/kg/kg) + (1.2 ha x 1.1 kg/ha x 1.04 x 1.1 x 1.05 x 0.234 mg/kg/kg)).

Table 2.16--Daily worker dose levels from spraying mid-sized, open-range projects.

| | Dose in mg/kg/day assuming minor mixing errors | Dose in mg/kg/day assuming a major mixing error |
|---|---|---|
| 2,4-D | 0.80 | 0.85 |
| Picloram | 0.40 | 0.43 |
| Dicamba | 0.40 | 0.43 |
| 2,4-D/ | 0.40 | 0.43 |
| Picloram | 0.10 | 0.11 |
| 2,4-D/ | 0.49 | 0.52 |
| Dicamba | 0.24 | 0.26 |
| Glyphosate | 0.40 | 0.43 |
| Amitrole | 0.40 | 0.43 |
| Atrazine | 0.80 | 0.85 |
| Hexazinone | 0.80 | 0.85 |

### 2.4.4.2 General Population, Direct Dose from Drift

Spraying will be treated as though it occurrs on a continuous 2.7-hectare site (6.6 acres) with dimensions of 200 meters by 135 meters. The spray zone is

assumed to be oriented such that the wind blows directly along the 200 meter length of the spray zone. Drift is calculated on the basis that half of theproject is 200 meters from the residence and half is 300 meters from the house (using factors from Table 2.5). Drift deposition at 200 meters from a day's spraying at 1.3 kg/ha (1.2 lb/ac) would be 0.078 $mg/m^2$ ((1.3 kg/ha x 1 x $10^6$ mg/kg x hectare/10,000 meters) x ((3.6 + 2.4) x $10^{-4}$)).

Dermal absorption rates and assumptions regarding area of exposed skin are identical to those used for small projects. Tables 2.17 through 2.23 present dose data for these residents on a daily basis.

Table 2.17--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with 2,4-D.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $8.2 \times 10^{-5}$ | $1.0 \times 10^{-4}$ |
| Adolescent dermal dose | $1.1 \times 10^{-4}$ | $1.3 \times 10^{-4}$ |
| Infant dermal dose | $2.0 \times 10^{-4}$ | $2.5 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $3.1 \times 10^{-3}$ | $3.9 \times 10^{-3}$ |
| Infant oral dose (veg) | $3.8 \times 10^{-3}$ | $4.7 \times 10^{-3}$ |
| Visitor re-entry to spray site | $5.1 \times 10^{-4}$ | $6.3 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $5.6 \times 10^{-2}$ | $6.8 \times 10^{-2}$ |

Table 2.18--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with picloram or amitrole.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $4.1 \times 10^{-6}$ | $5.3 \times 10^{-6}$ |
| Adolescent dermal dose | $5.3 \times 10^{-6}$ | $6.5 \times 10^{-6}$ |
| Infant dermal dose | $9.8 \times 10^{-6}$ | $1.2 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.5 \times 10^{-3}$ | $1.9 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.9 \times 10^{-3}$ | $2.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $2.6 \times 10^{-4}$ | $3.2 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

Table 2.19--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with hexazinone.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $8.3 \times 10^{-5}$ | $1.0 \times 10^{-4}$ |
| Adolescent dermal dose | $1.1 \times 10^{-4}$ | $1.3 \times 10^{-4}$ |
| Infant dermal dose | $2.0 \times 10^{-4}$ | $2.5 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.5 \times 10^{-3}$ | $1.9 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.9 \times 10^{-3}$ | $2.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $5.1 \times 10^{-4}$ | $6.3 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

Table 2.20--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with glyphosate or dicamba.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $4.1 \times 10^{-5}$ | $5.3 \times 10^{-5}$ |
| Adolescent dermal dose | $5.3 \times 10^{-5}$ | $6.4 \times 10^{-5}$ |
| Infant dermal dose | $9.8 \times 10^{-5}$ | $1.2 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.5 \times 10^{-3}$ | $1.9 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.9 \times 10^{-3}$ | $2.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $2.6 \times 10^{-4}$ | $3.2 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

Table 2.21--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/picloram mixture.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $4.1 \times 10^{-5}$<br>$1.0 \times 10^{-6}$ | $5.3 \times 10^{-5}$<br>$1.3 \times 10^{-6}$ |
| Adolescent dermal dose | $5.3 \times 10^{-5}$<br>$1.3 \times 10^{-6}$ | $6.4 \times 10^{-5}$<br>$1.6 \times 10^{-6}$ |
| Infant dermal dose | $9.8 \times 10^{-5}$<br>$2.4 \times 10^{-6}$ | $1.2 \times 10^{-4}$<br>$3.0 \times 10^{-6}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.5 \times 10^{-3}$<br>$4.0 \times 10^{-4}$ | $1.9 \times 10^{-3}$<br>$5.0 \times 10^{-4}$ |
| Infant oral dose (veg) | $1.9 \times 10^{-3}$<br>$5.0 \times 10^{-4}$ | $2.4 \times 10^{-3}$<br>$6.0 \times 10^{-4}$ |
| Visitor re-entry to spray site | $2.6 \times 10^{-4}$<br>$6.5 \times 10^{-5}$ | $3.2 \times 10^{-4}$<br>$8.0 \times 10^{-5}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$<br>$7.0 \times 10^{-3}$ | $3.4 \times 10^{-2}$<br>$8.5 \times 10^{-3}$ |

Table 2.22--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/dicamba mixture.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $5.0 \times 10^{-5}$<br>$2.5 \times 10^{-5}$ | $5.8 \times 10^{-5}$<br>$2.9 \times 10^{-5}$ |
| Adolescent dermal dose | $6.5 \times 10^{-5}$<br>$3.2 \times 10^{-5}$ | $8.1 \times 10^{-5}$<br>$4.0 \times 10^{-5}$ |
| Infant dermal dose | $1.2 \times 10^{-4}$<br>$6.0 \times 10^{-5}$ | $1.6 \times 10^{-4}$<br>$8.0 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$<br>$7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$<br>$8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $1.9 \times 10^{-3}$<br>$9.5 \times 10^{-4}$ | $2.2 \times 10^{-3}$<br>$1.1 \times 10^{-3}$ |
| Infant oral dose (veg) | $2.4 \times 10^{-3}$<br>$1.2 \times 10^{-3}$ | $3.1 \times 10^{-3}$<br>$1.5 \times 10^{-3}$ |
| Visitor re-entry to spray site | $3.2 \times 10^{-4}$<br>$1.6 \times 10^{-4}$ | $4.0 \times 10^{-4}$<br>$2.0 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $3.4 \times 10^{-2}$<br>$1.7 \times 10^{-2}$ | $4.2 \times 10^{-2}$<br>$2.1 \times 10^{-2}$ |

Table 2.23--Worst-case dose levels to visitors and residents in the vicinity of a mid-sized, open-range project sprayed with atrazine.

| | Dose including minor mixing error (mg/kg/day) | Dose including major mixing error (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $8.3 \times 10^{-5}$ | $1.0 \times 10^{-4}$ |
| Adolescent dermal dose | $1.1 \times 10^{-4}$ | $1.3 \times 10^{-4}$ |
| Infant dermal dose | $2.0 \times 10^{-4}$ | $2.5 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-3}$ | $7.1 \times 10^{-3}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-3}$ | $8.3 \times 10^{-3}$ |
| Adult/adolescent oral dose (veg) | $1.5 \times 10^{-3}$ | $1.9 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.9 \times 10^{-3}$ | $2.4 \times 10^{-3}$ |
| Visitor re-entry to spray site | $5.2 \times 10^{-4}$ | $6.3 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $3.4 \times 10^{-2}$ |

2.4.4.3 General Population, Oral Doses

The oral doses from consumption of cattle fed on herbicide-treated grass are the same as for small, open-range. In both cases, it is assumed that the cattle feed on herbicide-treated grass to the point of maximum herbicide body-burden (i.e., steady state, where herbicide intake is matched by excretion). In reality, because of the interspersed nature of herbicide applications, the reluctance of cattle to graze on knapweed, leafy spurge, and thistle (sprayed or otherwise), and the tendency of foraging cattle to move about, the actual dose to cattle and subsequent dose to humans would be much less than that indicated for either small or mid-sized projects.

As with the dermal dose to residents near mid-sized projects, the oral dose to residents from drift contaminated vegetables is calculated on the basis that a days' spraying covers a continuous area of dimensions 200 meters by 135 meters. Drift deposition factors from Table 2.6 for the distances of 200 meters and 300 meters are combined when calculating drift concentration on vegetation. Drift deposition on vegetation downwind from a site sprayed at 1.3 kg/ha (1.2 lb/ac) would be 0.47 mg/kg of vegetation ((0.21 mg-ha/kg$^2$ + 0.15 mg-ha/kg$^2$) x 1.3 kg/ha)). Daily dose to a 70 kg adult consuming 0.23 kg (8 oz) of vegetables (assuming no loss of herbicide in washing or cooking) would be $1.5 \times 10^{-3}$ mg/kg (0.47 mg/kg x 0.23 kg/adult x adult/70 kg).

2.4.4.4 General Population, Reentry and Oral Doses

Visitor doses are calculated as for small projects. A visitor is assumed to reenter a daily spray site shortly after spraying.

As discussed in Section 2.4.3.4, the visitor doses calculated in this analysis are very extreme estimates. The chances of picking and consuming one-half pound of wild foods exclusively from noxious weed sites that have been directly sprayed with herbicides are extremely small. Even smaller is the probability of a person picking and consuming wild foods from an area that has been mistakenly sprayed with a double-strength batch of herbicide mixture. The odor and taste of the sprayed vegetation alone would alert the person to contamination. For example, at concentrations above 5 mg/kg on food, both picloram and 2,4-D impart a bitter taste to food, thus limiting exposure.

2.4.5 Affected Population Doses from Large, Open-Range Projects

2.4.5.1 Worker Doses, Large Projects

Large, open-range projects will most often be sprayed with vehicle-mounted spray equipment. Areas inaccessible to vehicles may be sprayed with backpack sprayers.

In calculating worker doses from large, open-range projects, it is assumed that 20 percent (100 acres) of the large, open-range project is sprayed with backpack sprayers by seven workers (six sprayers and one supervisor) for 5 work days each. This application rate is equivalent to 1.3 net hectares (3.3 acres) per sprayer per day. The remainder of the project is sprayed with a vehicle-mounted spray rig in 5 days by one driver who also does his own mixing and loading of herbicide. As discussed in Section 2.2, double-strength applications are assumed to occur on 1 percent of the acreage sprayed with backpack sprayers. Double-strength mixing is not considered a possibility with

vehicle application because of the vast and obvious increase in pesticide consumption which would result. As discussed in Section 2.2, a 10 percent excess in herbicide concentration in the field mixture, a 4 percent excess formulation error, and 5 percent swath overlap is assumed for all vehicle applications.

The effect of a double-strength application by backpack sprayer exposure would be most apparent to the sprayer himself. Even here the effect is small as shown on Table 2.24. The effect on exposure levels for supervisor, residents, etc., would be negligible relative to the other 50 to 100 kilograms (100 to 200 pounds) of herbicide applied during each of the 5 days of spraying.

Tables 2.24 and 2.25 present the worst-case estimates for worker daily doses for large projects. As with mid-sized projects, backpack sprayer dose was calculated by multiplying the area sprayed per day (1.3 net hectares or 3.3 net acres) by the herbicide application rate per acre (see Table 2.7) and by the backpack dose factor of 0.234 or 0.468 mg/kg/kg (see Table 2.4). The truck driver dose was calculated by multiplying the area sprayed per day (32 hectares or 80 acres) by the minor mixing error application rate from Table 2.7 and by the truck driver/mixer/loader factor of $7.6 \times 10^{-3}$ or $1.52 \times 10^{-2}$ mg/kg/kg (see Table 2.4). Since the supervisor would be affected both by vehicle application and backpack spray, his dose was calculated on a 100-acre basis. As shown on Table 2.25, the supervisor dose is much smaller than either the backpack sprayer or truck driver dose. On this basis it can be safely assumed that the effect of the backpacker spray drift on the truck driver (or the reverse) would be negligible in comparison to the dose from his own spraying.

Table 2.24--Worst-case daily dose levels for backpack sprayers on large, open-range projects.

| | Dose in mg/kg/day assuming minor mixing errors | Dose in mg/kg/day assuming major mixing error on 1 acre |
|---|---|---|
| 2,4-D | 0.80 | 0.85 |
| Picloram | 0.40 | 0.43 |
| Dicamba | 0.40 | 0.43 |
| 2,4-D/ | 0.40 | 0.43 |
| picloram | 0.10 | 0.11 |
| 2,4-D/ | 0.49 | 0.52 |
| dicamba | 0.24 | 0.26 |
| Glyphosate | 0.40 | 0.43 |
| Amitrole | 0.40 | 0.43 |
| Atrazine | 0.80 | 0.85 |
| Hexazinone | 0.80 | 0.85 |

Table 2.25--Worst-case daily dose levels for truck drivers and supervisors on large, open-range projects.

| | Supervisor dose in mg/kg/day | Truck driver dose in mg/kg/day |
|---|---|---|
| 2,4-D | $8.0 \times 10^{-3}$ | 0.66 |
| Picloram | $4.0 \times 10^{-3}$ | 0.33 |
| Dicamba | $4.0 \times 10^{-3}$ | 0.33 |
| 2,4-D/ | $4.0 \times 10^{-3}$ | 0.33 |
| picloram | $1.0 \times 10^{-3}$ | 0.08 |
| 2,4-D/ | $4.9 \times 10^{-3}$ | 0.40 |
| dicamba | $2.4 \times 10^{-3}$ | 0.20 |
| Glyphosate | $4.0 \times 10^{-3}$ | 0.33 |
| Amitrole | $4.0 \times 10^{-3}$ | 0.33 |
| Atrazine | $8.0 \times 10^{-3}$ | 0.66 |
| Hexazinone | $8.0 \times 10^{-3}$ | 0.66 |

2.4.5.2 General Population, Direct Dose from Drift

Tables 2.26 through 2.29 present dose levels for residents and visitors in the vicinity of these large projects. As discussed in Section 2.1.3, one residence is assumed at 200 meters from the nearest edge of each of the large spray projects. Further, it is assumed that the 500-acre spray project (1,400 meters by 1,450 meters) is sprayed in five strips of 290-meters width by 1,400 meters (one strip sprayed each day). Finally, it is assumed that the wind blows parallel with the long axis of the sprayed area. This long and narrow spray pattern oriented with the long axis into the wind will provide the highest daily drift deposition from this large project.

Drift from each of the daily spray areas (1,400 by 290 meters) is calculated using data derived from Yates et al. (1978) for 100-meter-wide strips. Total daily drift from a large project sprayed at 1.3 kg/ha (nominal rate of 1.1 kg/ha or 1 pound/ac) can be calculated by multiplying the sum of the drift factors for 200 through 1,600 yards (Table 2.5) by the application rate of 1.3 kg/ha.

Based on these calculations, total daily drift deposition on surfaces at 200 meters distance from a large project sprayed at 1.3 kg/ha (1.2 lb/ac) would be 0.20 mg/$m^2$ (0.02 mg/foot$^2$). Dermal absorption is calculated assuming that the residents are outside the entire day during spraying, that the adults have 0.37 $m^2$ (4 $ft^2$) of exposed skin; adolescents, 0.27 $m^2$ (3 $ft^2$); and infants, 0.15 $m^2$ (1.6 $ft^2$). The dermal absorption rate for picloram and amitrole is assumed to be 1 percent; for glyphosate, dicamba, and 2,4-D, 10 percent; and for atrazine and hexazinone, 20 percent.

Table 2.26--Worst-case dose levels to visitors and residents in the vicinty of a large, open-range project sprayed with a 2,4-D, picloram, or amitrole.

| | 2,4-D dose (mg/kg/day) | Picloram or Amitrole dose (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $2.2 \times 10^{-4}$ | $1.1 \times 10^{-5}$ |
| Adolescent dermal dose | $3.0 \times 10^{-4}$ | $1.5 \times 10^{-5}$ |
| Infant dermal dose | $5.4 \times 10^{-4}$ | $2.7 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $9.6 \times 10^{-3}$ | $4.8 \times 10^{-3}$ |
| Infant oral dose (veg) | $1.2 \times 10^{-2}$ | $6.2 \times 10^{-3}$ |
| Visitor re-entry to spray site | $8.0 \times 10^{-3}$ | $4.0 \times 10^{-3}$ |
| Oral dose/ sprayed wild food | $5.6 \times 10^{-2}$ | $2.8 \times 10^{-2}$ |

Table 2.27--Worst-case dose levels to visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/picloram mixture.

| | 2,4-D dose (mg/kg/day) | Picloram dose (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $1.1 \times 10^{-4}$ | $3.0 \times 10^{-6}$ |
| Adolescent dermal dose | $1.5 \times 10^{-4}$ | $4.0 \times 10^{-6}$ |
| Infant dermal dose | $2.7 \times 10^{-4}$ | $7.0 \times 10^{-6}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $4.8 \times 10^{-3}$ | $1.2 \times 10^{-3}$ |
| Infant oral dose (veg) | $6.2 \times 10^{-3}$ | $1.6 \times 10^{-3}$ |
| Visitor re-entry to spray site | $4.0 \times 10^{-4}$ | $1.1 \times 10^{-4}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $7.0 \times 10^{-3}$ |

Table 2.28--Worst-case dose levels to visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/dicamba mixture.

| | 2,4-D dose (mg/kg/day) | Dicamba dose (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $1.4 \times 10^{-4}$ | $7.0 \times 10^{-5}$ |
| Adolescent dermal dose | $1.8 \times 10^{-4}$ | $9.0 \times 10^{-5}$ |
| Infant dermal dose | $3.3 \times 10^{-4}$ | $1.7 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ |
| Adult/adolescent oral dose (veg) | $6.2 \times 10^{-3}$ | $3.1 \times 10^{-3}$ |
| Infant oral dose (veg) | $7.6 \times 10^{-3}$ | $3.8 \times 10^{-3}$ |
| Visitor re-entry to spray site | $4.9 \times 10^{-3}$ | $2.4 \times 10^{-3}$ |
| Oral dose/ sprayed wild food | $3.4 \times 10^{-2}$ | $1.7 \times 10^{-2}$ |

Table 2.29--Worst-case dose levels to visitors and residents in the vicinity of a large, open-range project sprayed with dicamba, glyphosate, hexazinone, or atrazine.

| | Dicamba or Glyphosate dose (mg/kg/day) | Hexazinone dose (mg/kg/day) | Atrazine dose (mg/kg/day) |
|---|---|---|---|
| Adult dermal dose | $1.1 \times 10^{-4}$ | $2.2 \times 10^{-4}$ | $2.2 \times 10^{-4}$ |
| Adolescent dermal dose | $1.5 \times 10^{-4}$ | $3.0 \times 10^{-4}$ | $3.0 \times 10^{-4}$ |
| Infant dermal dose | $2.7 \times 10^{-4}$ | $5.4 \times 10^{-4}$ | $5.4 \times 10^{-4}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-4}$ | $7.1 \times 10^{-3}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-4}$ | $8.3 \times 10^{-3}$ |
| Adult/adolescent oral dose (veg) | $4.8 \times 10^{-3}$ | $4.8 \times 10^{-3}$ | $4.8 \times 10^{-3}$ |
| Infant oral dose (veg) | $6.2 \times 10^{-3}$ | $6.2 \times 10^{-3}$ | $6.2 \times 10^{-3}$ |
| Visitor re-entry to spray site | $4.0 \times 10^{-3}$ | $8.0 \times 10^{-3}$ | $8.0 \times 10^{-3}$ |
| Oral dose/ sprayed wild food | $2.8 \times 10^{-2}$ | $2.8 \times 10^{-2}$ | $2.8 \times 10^{-2}$ |

2.4.5.3 General Population, Oral Doses

Oral doses to humans from eating beef grazing on herbicide-treated grassland are calculated in an identical fashion as for small and mid-sized projects. These dose values are also provided on Tables 2.26 through 2.29.

The dose from eating drift-contaminated vegetables from a garden is calculated in a fashion similar to the dermal doses from drift. Drift deposition on vegetables is calculated by combining factors for 100-meter-wide swaths from Table 2.6 for 200- through 1,600-meter distances. Daily vegetable consumption rates were as for small and mid-sized projects: adults, 0.23 kilograms (8 ounces); adolescents 0.13 kilograms (5 ounces); and infants 0.05 kilograms (2 ounces). Once again, no loss of herbicide was assumed during washing and cooking. Tables 2.26 through 2.29 present oral doses from eating drift-contaminated vegetables.

2.4.5.4 General Population, Reentry and Oral Doses

Tables 2.26 through 2.29 also provide worst-case dose levels for visitor reentry to spray sites and visitor consumption of wild food gathered from spray sites. These daily dose rates were calculated as for small and mid-sized projects. The dose from wild food consumption is very unlikely because, aside from the fact that a very small percentage of National Forest System land will be sprayed, those noxious weed sites that are sprayed have little or no vegetation that is edible by humans (e.g., huckleberries, mushrooms, etc.). The odor and taste of edible wild food sprayed at concentrations necessary to give the doses reported here would also diminish the possibility of human consumption.

2.4.6 Affected Population Exposure and Dose from Right-of-Way Projects

2.4.6.1 Worker Doses

As discussed in Section 2.1.4, the right-of-way spray project is assumed to require one truck driver and a coworker who spot sprays with a hand-held spray nozzle or backpack sprayer. These two workers spray this right-of-way project in a day. Each project is assumed to involve a 6-meter-wide swath (10 miles) sprayed along 16 kilometers of roadside (5 miles of road both sides). The truck is assumed to cover 8 hectares (20 acres) and the spot sprayer an additional 1.3 hectares (3.3 acres).

Daily dose levels for the two workers are included in Table 2.30. These dose levels assume a 10 percent mixing error, 4 percent formulation error, and a 5 percent double swath. As with the open-range projects, the worker dose was calculated by multiplying the presumed daily application rate (Table 2.31) by the area sprayed and by the dose factor for a truck driver or a backpack sprayer from Table 2.4. For example, the truck driver dose for a 1.3 kg/ha application of picloram would be 0.08 mg/kg (8 ha x 1.3 kg/ha x $7.6 \times 10^{-3}$ mg/kg/kg).

Table 2.30 provides worker doses for the herbicides glyphosate, amitrole, atrazine, and hexazinone based on an assumed application rate of 1.3 kg/ha (1.2 lb/ac). These herbicides are not now used on Region 1 right-of-way projects.

Table 2.30--Worst-case worker dose levels from spraying of right-of-way projects for 1 day.

| | Truck driver dose in mg/kg/day | Spot sprayer dose in mg/kg/day |
|---|---|---|
| 2,4-D | 0.16 | 0.80 |
| Picloram | 0.08 | 0.40 |
| Dicamba | 0.08 | 0.40 |
| 2,4-D/ | 0.08 | 0.40 |
| picloram | 0.02 | 0.10 |
| 2,4-D/ | 0.10 | 0.49 |
| dicamba | 0.05 | 0.24 |
| Glyphosate | 0.08 | 0.40 |
| Amitrole | 0.08 | 0.40 |
| Atrazine | 0.16 | 0.80 |
| Hexazinone | 0.16 | 0.80 |

Table 2.31--Application rates including mixing errors and swath overlap for right-of-way projects.

| | Application rate (kg/ha) | Application rate (pound/ac) |
|---|---|---|
| 2,4-D | 2.6 | 2.4 |
| Picloram | 1.3 | 1.2 |
| Dicamba | 1.3 | 1.2 |
| 2,4-D/ | 1.3 | 1.2 |
| picloram | 0.36 | 0.3 |
| 2,4-D/ | 1.6 | 1.4 |
| dicamba | 0.8 | 0.7 |
| Glyphosate | 1.3 | 1.2 |
| Amitrole | 1.3 | 1.2 |
| Atrazine | 1.3 | 1.2 |
| Hexazinone | 1.3 | 1.2 |

2.4.6.2 General Population, Direct Dose from Drift

As discussed in Section 2.3.4, a residence with four inhabitants is assumed to be located 60 meters (200 feet) downwind of the right-of-way spray project. As with the other model projects, all residents are assumed to be outdoors during the entire project. In addition, the adolescent is assumed to be attracted by the sound and sight of the spray equipment and to approach and stand immediately adjacent to the road right-of-way during spraying.

Dermal dose values for residents who are 60 meters from a spray area are calculated as were dermal doses from drift from open-range projects. Drift deposition factors for 60 meters are available on Table 2.5.

The drift deposition factor from Table 2.5 is adjusted for the fact that the right-of-way project involves two 6-meter-wide swaths (one on each side of the road) and the drift factors in Table 2.5 are based on a 10-meter-wide swath. Drift deposition at 60 meters from a 1.3 kg/ha (1.2 lb/ac) application rate is calculated to be 0.037 mg/$m^2$ (24 x $10^{-5}$ x 12 meter/10 meter x 1.3 kg/ha x 1,000,000 mg/kg x ha/10,000 $m^2$).

Assuming 0.37 $m^2$ (4 $ft^2$) of exposed skin and a 10 percent absorption rate, the dermal dose to a 70 kg person would be 2.0 x $10^{-5}$ mg/kg (0.37 $m^2$/person x 0.1 x person/70 kg x 0.037 mg/$m^2$).

There are several ways to estimate the dose to an adolescent in the immediate vicinity of a spray area. One method is to assume that his exposure would not be greater than a supervisor or project observer who spends an entire day on a large spray project (8.1 x $10^{-3}$ mg/kg or less).

A second method of estimating dose to a bystander will provide a higher estimate. This method is based on estimates of spray deposition at short distances off-target and estimates of the dermal absorption rate of herbicides.

Maybank et al. (1977) have made numerous tests to measure deposition on target as well as deposition within 5 meters off-target during spraying with ground rigs. In the 30 trials with wind speeds up to 33 km/hr (20 mph), the highest concentration drift cloud measured with air samplers at 1 meter from the spray site was equivalent to 25.2 mg/$m^2$. This drift cloud resulted from an application of 0.56 kg/ha (0.5 lb/ac) on a 13.6-meter-wide swath (45 feet).

Maybank's findings must be adjusted for the fact that the right-of-way spray area would be less than half as wide as the strips sprayed by Maybank and his coworkers, although the right-of-way may be sprayed at a higher rate. For example, a 2.6 kg/ha application rate on the 6-meter-wide right-of-way would be equivalent to a 1.2 kg/ha application on the 13.6-meter-wide strip. Drift deposit adjusted to this 1.2 kg/ha rate would be 54 mg/$m^2$ (1.2 kg/ha/0.56 kg/ha x 25.2 mg/$m^2$). Assuming 0.27 $m^2$ of exposed skin (3 $ft^2$), deposition would be 15 mg on bare skin (54 mg/$m^2$ x 0.27 $m^2$). Assuming a 10 percent absorption rate, the dose to a 40 kg adolescent would be 0.038 mg/kg (0.1 x 15 mg/40 kg). This estimate can be considered extremely high since it is about 5 times the dose based on measurements of supervisors spending an entire day in the immediate vicinity of a spray site.

2.4.6.3 General Population, Oral Dose, Beef and Vegetation

Since cattle do not routinely graze on most rights-of-way sprayed by the Forest Service, herbicide dose to cattle will be greatly reduced. Work by Maybank et al. (1977) has shown that within 5 meters of a 13-meter-wide, ground-rig spray swath, drift deposits on horizontal surfaces would be less than 1 percent of the nominal application rate on target. Thus, dose to cattle and subsequent dose to humans is assumed to be 1 percent of the doses calculated for open-range projects.

Oral dose from eating spray-contaminated vegetables is calculated using the same consumption rates as in the open-range project scenarios. Vegetable gardens are assumed to be located 60 meters from the spray project. Spray deposition factors for vegetation predicated on a 10-meter-wide spray swath are provided on Table 2.6. Spray factors for 60 meters' distance are, therefore, multiplied by 1.2 to account for the difference in width in a double-swath right-of-way project. Oral dose for a 70 kg adult consuming 0.23 kg (0.5 lbs) of vegetables daily is calculated on the assumption that no loss of herbicide occurs in washing or cooking. Worst-case adult daily dose based on an application rate of 1.3 kg/ha (1.2 lb/ac), is $5.1 \times 10^{-4}$ mg/kg (1.2 x 1.3 kg/ha x 0.1 mg/kg$^2$-ha x 0.23 kg/person x person/70 kg).

As a worst-case approximation of the dose to a person who walks through the right-of-way shortly after spraying the right-of-way, the dose factors from Table 2.4 for a supervisor present during the entire spray project will be used. The dose from a 9-hectare (22-acre) right-of-way project sprayed with picloram at 1.3 kg/ha (1.2 lbs/ac) would be $8.8 \times 10^{-4}$ mg/kg (9 ha x 1.3 kg/ha x 0.075 x $10^{-3}$ mg/kg$^2$).

The general population doses from drift and reentry and oral doses from various sources are provided on Tables 2.32 through 2.34.

Table 2.32--Worst-case daily dose levels to visitors and residents in the vicinity of right-of-way projects sprayed with 2,4-D, picloram, amitrole, or dicamba.

| | 2,4-D dose (mg/kg/day) | Picloram or Amitrole dose (mg/kg/day) | Dicamba dose (mg/kg/day) |
|---|---|---|---|
| Adult dermal dose | $4.0 \times 10^{-5}$ | $2.0 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| Adolescent dermal dose | $3.8 \times 10^{-2}$ | $1.9 \times 10^{-3}$ | $1.9 \times 10^{-2}$ |
| Infant dermal dose | $9.6 \times 10^{-5}$ | $4.8 \times 10^{-6}$ | $4.8 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-6}$ | $7.1 \times 10^{-6}$ | $7.1 \times 10^{-6}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-6}$ | $8.3 \times 10^{-6}$ | $8.3 \times 10^{-6}$ |
| Adult/adolescent oral dose (veg) | $1.0 \times 10^{-3}$ | $5.1 \times 10^{-4}$ | $5.1 \times 10^{-4}$ |
| Infant oral dose (veg) | $1.3 \times 10^{-3}$ | $6.5 \times 10^{-4}$ | $6.5 \times 10^{-4}$ |
| Visitor re-entry or walk along ROW | $1.76 \times 10^{-3}$ | $8.8 \times 10^{-4}$ | $8.8 \times 10^{-4}$ |
| Adult oral dose (water) | $5.8 \times 10^{-3}$ | $2.9 \times 10^{-3}$ | $2.9 \times 10^{-3}$ |
| Adolescent oral dose (water) | $7.6 \times 10^{-3}$ | $3.8 \times 10^{-3}$ | $3.8 \times 10^{-3}$ |
| Infant oral dose (water) | $8.3 \times 10^{-3}$ | $4.2 \times 10^{-3}$ | $4.2 \times 10^{-3}$ |
| Adult/adolescent oral dose (fish) | $1.0 \times 10^{-4}$ | $4.8 \times 10^{-5}$ | $4.8 \times 10^{-5}$ |
| Infant oral dose (fish) | $1.1 \times 10^{-4}$ | $5.6 \times 10^{-5}$ | $5.6 \times 10^{-5}$ |

Table 2.33--Worst-case daily dose to residents in the vicinity of right-of-way projects sprayed with mixtures of 2,4-D/picloram, or 2,4-D/dicamba.

| | 2,4-D/picloram dose (mg/kg/day) | 2,4-D/Dicamba dose (mg/kg/day) |
|---|---|---|
| Adult dermal dose | $2.0x10^{-5}/5.0x10^{-7}$ | $2.5x10^{-5}/1.2x10^{-5}$ |
| Adolescent dermal dose | $1.9x10^{-2}/5.0x10^{-4}$ | $2.4x10^{-2}/1.2x10^{-2}$ |
| Infant dermal dose | $4.8x10^{-5}/1.2x10^{-6}$ | $6.0x10^{-5}/3.0x10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1x10^{-6}/7.1x10^{-6}$ | $7.1x19^{-6}/7.1x10^{-6}$ |
| Infant oral dose (beef) | $8.3x10^{-6}/8.3x10^{-6}$ | $8.3x10^{-6}/8.3x10^{-6}$ |
| Adult/adolescent oral dose (veg) | $5.1x10^{-4}/1.3x10^{-4}$ | $6.2x10^{-4}/3.1x10^{-4}$ |
| Infant oral dose (veg) | $6.5x10^{-4}/1.5x10^{-4}$ | $8.0x10^{-4}/4.0x10^{-4}$ |
| Visitor re-entry or walk along ROW | $8.8x10^{-4}/2.3x10^{-4}$ | $1.1x10^{-3}/5.0x10^{-4}$ |
| Adult oral dose (water) | $2.9x10^{-3}/7.2x10^{-4}$ | $3.6x10^{-3}/1.8x10^{-3}$ |
| Adolescent oral dose (water) | $3.8x10^{-3}/1.0x10^{-3}$ | $4.7x10^{-3}/2.3x10^{-3}$ |
| Infant oral dose (water) | $4.2x10^{-3}/1.1x10^{-3}$ | $5.1x10^{-3}/2.5x10^{-3}$ |
| Adult/adolescent oral dose (fish) | $4.8x10^{-5}/1.7x10^{-5}$ | $6.2x10^{-5}/3.1x20^{-5}$ |
| Infant oral dose (fish) | $5.6x10^{-5}/1.9x10^{-5}$ | $6.9x10^{-5}/3.5x10^{-5}$ |

Table 2.34--Worst-case daily dose to visitors and residents in the vicinity of right-of-way projects sprayed with glyphosate, hexazinone, or atrazine.

| | Glyphosate dose (mg/kg/day) | Hexazinone dose (mg/kg/day) | Atrazine dose (mg/kg/day) |
|---|---|---|---|
| Adult dermal dose | $2.0 \times 10^{-5}$ | $4.0 \times 10^{-5}$ | $4.0 \times 10^{-5}$ |
| Adolescent dermal dose | $1.9 \times 10^{-2}$ | $3.8 \times 10^{-2}$ | $3.8 \times 10^{-2}$ |
| Infant dermal dose | $4.8 \times 10^{-5}$ | $9.6 \times 10^{-5}$ | $9.6 \times 10^{-5}$ |
| Adult/adolescent oral dose (beef) | $7.1 \times 10^{-6}$ | $7.1 \times 10^{-6}$ | $7.1 \times 10^{-5}$ |
| Infant oral dose (beef) | $8.3 \times 10^{-6}$ | $8.3 \times 10^{-6}$ | $8.3 \times 10^{-5}$ |
| Adult/adolescent oral dose (veg) | $5.1 \times 10^{-4}$ | $5.1 \times 10^{-4}$ | $5.1 \times 10^{-4}$ |
| Infant oral dose (veg) | $6.5 \times 10^{-4}$ | $6.5 \times 10^{-4}$ | $6.5 \times 10^{-4}$ |
| Visitor re-entry or walk along ROW | $8.8 \times 10^{-4}$ | $1.76 \times 10^{-3}$ | $1.76 \times 10^{-3}$ |
| Adult oral dose (water) | $2.9 \times 10^{-3}$ | $2.9 \times 10^{-3}$ | $2.9 \times 10^{-3}$ |
| Adolescent oral dose (water) | $3.8 \times 10^{-3}$ | $3.8 \times 10^{-3}$ | $3.8 \times 10^{-3}$ |
| Infant oral dose (water) | $4.2 \times 10^{-3}$ | $4.2 \times 10^{-3}$ | $4.2 \times 10^{-3}$ |
| Adult/adolescent oral dose (fish) | $4.8 \times 10^{-5}$ | $2.4 \times 10^{-4}$ | $2.4 \times 10^{-4}$ |
| Infant dose (fish) | $5.6 \times 10^{-5}$ | $2.8 \times 10^{-4}$ | $2.8 \times 10^{-4}$ |

2.4.6.4 General Population, Doses from Aquatic Contamination

As discussed in Section 2.1.4, many road rights-of-way are located relatively close to stream channels. Herbicide applications could affect water quality through drift into the stream at the time of application and through runoff into the stream during subsequent rainstorms.

Estimates of the drift into nearby streams can be made using research findings by Maybank et al. (1977). As discussed above, Maybank has shown that within 5 meters of a 13-meter-wide ground-rig spray swath, drift deposits on horizontal surfaces would be less than 1 percent of the nominal application rate on target. Assuming a stream averaging 3 feet wide, 4 inches deep, and flowing at 1 cubic foot per second (CFS), the drift deposition onto 8 kilometers of stream adjacent to the spray project would total 10,400 mg (1.3 kg/ha X 0.01 X 1 meter X 8,000 meters X ha/10,000 meters$^2$ X 1,000,000 mg/kg). The drift deposition would be diluted into the water that flowed past the project in the 6 hours (21,600 seconds) during which spraying occurred. Thus, the maximum concentration at any time would be 0.017 mg/liter (10,400 mg X sec/1 ft$^3$ X ft$^3$/28.3 liter X 1/21,600 seconds).

Maximum in-stream concentrations from herbicide-contaminated runoff will be highly dependent on site-specific characteristics. Table 2.35 provides a listing of numerous studies that have measured herbicide run-off concentrations adjacent to spray areas. The review articles listed on this table (such as Norris 1981) summarize available literature on a herbicide and thus incorporate data from numerous studies.

The literature review indicates several things. Even when run-off concentrations are measured at the edge of large application areas, maximum run-off concentrations are less than 1 mg/liter and typically less than 0.1 mg/liter (with adjustments made for application rates). These maximum concentrations occur for a very short period, typically during the first significant rainfall after application. These concentrations are the maximum that might occur adjacent to the project, for example, in a drainage ditch or culvert. Concentrations in stream water would be 10 to 100 times less because of dilution with the base flow of the stream. Thus, the maximum concentration in stream water would be 0.1 mg/liter or less.

Table 2.35--Summary of references for herbicide concentrations in runoff.

| Pesticide | References |
|---|---|
| 2,4-D | Review by Norris 1981 |
| Picloram | Davis and Ingebo 1973 |
| | Baur et al. 1972 |
| | Bovey et al. 1974 and 1975 |
| | Mayeux et al. 1984 |
| | Norris et al. 1982 |
| | Neary et al. 1985. |
| Dicamba | Trichell et al. 1968 |
| | Schwab et al. 1973 |
| Glyphosate | Edwards et al. 1980 |
| | Newton et al. 1984 |
| Hexazinone | Bouchard et al. 1985 |
| | Neary et al. 1983 |
| Amitrole | Marston et al. 1968 |
| | Norris 1968 |
| Atrazine | Review in USDA 1984 |

As a check on the reasonableness of this concentration estimate, it is also possible to calculate in-stream concentrations based on the total quantity of herbicide that might be lost in runoff. Studies with picloram and hexazinone, the most mobile of the herbicides of interest, have shown that between 0.35 percent and 6.0 percent of the total applied herbicde is lost in runoff in time periods ranging from months to years (see Mayeux et al. 1984; Davis and Ingebo 1973; Norris et al. 1982; Bouchard et al. 1985; and Neary et al. 1983). Assuming, for example, that 2 percent of the applied herbicide was lost in runoff in a 24-hour period and that none was degraded or adsorbed by sediments, the herbicide concentration in a 1 cfs stream adjacent to a 1.3 kg/ha application would be 0.10 mg/L (1.3 kg/ha X 9.6 ha X 0.02 X 1,000,000 mg/kg X 1.28.3 liters/sec X 1/86,400 sec).

A 70 kg adult who drank in a day 2 liters of water with a herbicide concentration of 0.1 mg/L would receive a dose of 0.0029 mg/kg (2 liters X 0.1 mg/liter X persons/70 kg). The doses to adolescents and infants assuming consumption of 1.5 liters and 0.5 liters of water, respectively, would be 0.0038 mg/kg and 0.0042 mg/kg, respectively.

An assumption of 2 percent loss in 24 hours will also be used when calculating maximum oral doses from application rates other than 1.3 kg/ha.

Aquatic organisms that are exposed to herbicides in water can absorb and retain some of the herbicide. Some pesticides such as DDT can accumulate at much higher levels in aquatic organisms (such as a fish) than in the ambient environment. Bioaccumulation factors of 60,000 to 90,000 are cited for DDT which means that after long-term exposure, DDT concentrations in the fish could be at least 60,000 times higher than in the water.

Agriculture Handbook 633 (USDA 1984) reviews the environmental fate and toxicological literature for the herbicides of interest in this risk analysis. This review indicates that bioaccumulation of 1.0 or less are indicated for all herbicides of interest here except hexazinone and atrazine, which might have factors as high as 5.0. Assuming that the herbicide concentration in the 15 cfs fishery stream were diluted 15 times from the roadside stream concentration (1 cfs/15 cfs), and that the fish in the stream can absorb herbicide to their maximum bioaccumulative capacity very quickly, the atrazine or hexazinone concentration in fish would be 0.033 m/kg (0.1 mg/L X 5.0 mg/kg/mg/L x 1/15).

The concentrations of the other herbicides would be less than one-fifth these concentrations.

Worst-case daily oral dose to a 70 kg fisherman who catches and consumes 0.5 kg (1.1 pounds) of fish contaminated with atrazine or hexazinone would be 2.4 X $10^{-4}$ mg/kg (0.033 mg/kg X 0.5 kg X person/70 kg). Adolescent and infant doses are based on assumed consumption of 0.3 kg and 0.1 kg of fish, respectively.

Actual doses from eating such fish would very probably be many times less since it typically takes many days of exposure to a given concentration of herbicide in water for a fish to bioaccumulate to the steady state maximum indicated by the bioaccumulation factors. The maximum water concentrations used in these dose calculations would likely never occur or would occur at most for a very few hours.

## 2.5 REVIEW OF GENERAL TOXICITY DATA FOR HERBICIDES

The significance of the dose levels developed in Sections 2.1 through 2.4 is determined in part by comparison to dose levels that produce general toxic effects. The toxic effects of a compound can be measured on any number of animal species using a variety of experimental protocol. The acute toxicity of a chemical compound is often indicated by the one-time or short-term dose that is lethal to 50 percent of a group of treated animals. This value is abbreviated as the $LD_{50}$ and is expressed as the mass unit of compound (usually in grams, milligrams, or micrograms) administered per mass unit of organism (usually in kilograms).

$LD_{50}$ values will vary among species tested. Because there is no universally accepted method for determining which animal species would provide the most suitable model for effects on man, the $LD_{50}$ value for the species most sensitive to a particular herbicide is reported on Table 2.36. These values are based on a review of herbicide toxicology data provided by Agriculture Handbook 633 (USDA 1984).

Because lethality represents a rather extreme benchmark for judging the safety of herbicides, policies regarding acceptable intake levels for chemical compounds are most often based on toxicity tests designed to find the highest dose level that produces no effects in the animal species tested. This dose is the no observed effect level (NOEL). The NOEL is the dose level below the lowest dose level to affect the organism's health or well being over the test duration. A NOEL can be determined for acute (single dose or short-term), subchronic (generally 30- to 90-day dosing studies), and chronic tests of a compound. All other things being equal, the longer the dosing duration upon which a NOEL is based for a particular animal species, the more significant the resulting value.

In registering herbicides for use on agricultural commodities for human consumption or on feed for animals subject to human consumption, the Environmental Protection Agency (EPA) establishes tolerances for residues of herbicide. These tolerance levels are based on the toxicity data establishing NOEL's for the herbicide and a projection of human consumption patterns. Generally, EPA uses the NOEL from the chronic dose studies with the species that is most sensitive to the compound. In the absence of chronic exposure test results with the most sensitive species, the EPA does use subchronic test results with larger safety factors and the requirement of additional chronic testing. Table 2.36 provides the NOEL's as used by EPA in setting tolerances for herbicide residues on human foodstuffs.

With the exception of picloram, all NOEL data proved on Table 2.36 are based on 2-year feeding studies with either dogs or rats. The most recent tolerance limit determination for picloram by EPA was based on a 90-day dog-feeding study with a NOEL of 50 mg/kg/day. In the interim, Dow Chemical has been conducting additional tests. A recently completed 6-month dog-feeding study showed a NOEL of 7 mg/kg/day (Dow undated). Dow Chemical is currently conducting a 2-year rat-feeding study as reported by Roby (1984). Six-month and 12-month interim data are available from these tests. At 6 months, some liver anomalies were

noted in animals dose at 60 mg/kg/day. However, these effects were not noted in animals sacrificed after 12 months of daily doses of 60 mg/kg. At 20 mg/kg/day, no effects were noted for either 6-month or 12-month dosing periods. Thus, 20 mg/kg/day would be a conservative interim NOEL value for this rat-feeding study.

Table 2.36--Summary of acute and chronic toxicity thresholds based on results with the most sensitive species.

| Herbicide | Acute oral[1] $LD_{50}$ in mg/kg | Chronic toxicity NOEL in mg/kg/day | Reference for NOEL data |
|---|---|---|---|
| Amitrole | 1,100 | 0.025[2] | USEPA, 1985c |
| Atrazine | 1,400 | 3.750 | Fed. Register 12/30/81, p. 63085 |
| 2,4-D | 100 | 1.0 | USEPA, 1985a |
| Dicamba | 566 | 1.250 | Fed. Register 3/16/83 p. 11119 |
| Glyphosate | 3,800 | 10.000 | Fed. Register 10/30/85 p. 45121 |
| Hexazinone | 860 | 10.000 | Fed. Register 8/17/83 p. 37214 |
| Picloram | 2,000 | 50.000 | Fed. Register 9/22/82 p. 41770 |
| | | 20.000 | Roby 1984 |
| | | 7.000 | Roby 1984 |

[1]Based on a review of Agriculture Handbook 633 (USDA 1984).

[2]Amitrole use is not permitted on agricultural commodities. This NOEL is based on a review by USEPA (1985c).

Because the dog-feeding study provided a lower NOEL value, the value of 7 mg/kg/day, as obtained in the 6-month dog study, will be used as the NOEL value in this risk analysis.

The use of pesticides can cause concern over the possible prenatal effects from the exposure of pregnant women to such pesticides. Teratogenesis refers to irreversible malformations caused early in the development of the fetus, when organs are just forming. Teratogenesis should be distinguished from the term, fetotoxicity. Fetotoxicity refers to reversible effects on the fetus, such as lowered birth weight, delays in ossification, etc. These effects can be overcome upon removal of the toxicant.

Fetotoxic effects are often noted at lower doses than teratogenic effects and NOEL's can be determined for both fetotoxic and teratogenic effects for the herbicides of interest. This analysis provides the NOEL values for fetotoxicity or teratogenicity whichever is lower.

Based on a review in the USDA Handbook Number 633 (USDA 1984), the fetotoxicity NOEL for amitrole is 100 ppm in diet (equivalent to 5 mg/kg based on food-to-body weight factor of 0.05 (USDA 1984)). As indicated in Table 2.36, the overall NOEL is 0.05 mg/kg, which indicates that fetotoxicity is less of a concern than amitrole's general toxic effects (antithyroid activity). A similar pattern is noted with most of the herbicides of interest here.

A value of 15 mg/kg is reported as the lowest fetotoxicity NOEL for atrazine (USDA 1984). By contrast the NOEL for any effect from atrazine dosing is 3.75 mg/kg.

The lowest fetotoxicity NOEL reported in USDA Handbook 633 (USDA 1984) for dicamba is 3 mg/kg. By comparison the overall NOEL for any effect is 1.25 mg/kg.

The herbicide 2,4-D has been subject to extensive study both in the past and as part of a data call-in for a review of registration data. A Russian fetotoxicity-teratogenicity study on 2,4-D has been reported to have shown fetotoxic effects at doses as low as 0.5 mg/kg (USDA 1984). Questions on the validity of this study have been raised because no information is available on impurities in the test compounds, solvents used, strain of rats used, etcetera. Because of this uncertainty, new testing has been conducted on 2,4-D. Recently a rat-feeding study on the teratogenic effects of 2,4-D has been conducted by Dow Chemical and a separate, independent feeding study completed by EPA. A fetotoxicity NOEL of 25 mg/kg was indicated by these studies and teratogenic effects were not induced (Spencer 1985).

The NOEL of 10 mg/kg/day reported for glyphosate on Table 2.36 is based on a three-generation reproduction study in rats. This NOEL was based on renal tubular dilation in kidneys of the pups; no effects on fertility or reproductive parameters were noted. Glyphosate is somewhat unusual because these reproductive effects occur at lower doses than do general systemic toxic effects. No general systemic toxic effects were noted at the highest dose tested (31 mg/kg/day) in a 2-year rat-feeding study (USEPA 1985d). In teratology studies no teratogenic effects were noted in rats at doses up to 1,000 mg/kg/day and in rabbits at doses up to 350 mg/kg/day.

Hexazinone and picloram have very low teratogenic potential. No teratogenic effects in rats were seen with hexazinone doses up to 5,000 ppm in food (250 mg/kg by body weight). For rabbits a fetotoxicity NOEL of 125 mg/kg is reported for hexazinone (lowest value reported in USDA 1984 or USEPA 1983b).

Teratogenic and fetotoxic effects are not seen with picloram doses up to 500 mg/kg in animal tests (USDA 1984).

Table 2.37 provides a summary of fetotoxicity NOEL values for the herbicides of interest. This table also provides a list of lifetime Acceptable Daily Intake (ADI) values as determined by EPA in setting tolerance limits for herbicides on agricultural commodities. The ADI values assume that a person can be dosed daily at this level for a lifetime with no ill effects.

The time-honored approach for establishing an ADI or safe level of pesticide dose is to divide the threshold dose or NOEL established from chronic animal studies by a "safety factor" (Doull et al. 1980 and NAS-NRC 1977). The safety factors are needed to account for differences in duration of exposure, absorption, metabolism, and excretion between humans and test animals. For example, on a body-weight basis, man is generally more vulnerable to drugs than are experimental animals by a factor of 6-12 (NAS-NRC 1977). If the dose is scaled on a surface area basis, this increased vulnerability disappears.

In addition to accounting for differences between animal species and humans (interspecies differences), the safety factor should also account for differences among humans (intraspecies differences). For example, for the herbicides atrazine, dicamba, 2,4-D, and glyphosate, the NOEL from chronic feeding studies with the most sensitive species was divided by 100 to arrive at the ADI. This safety factor of 100 can be considered to include a tenfold safety factor to account for the difference between animal species and humans and an additional tenfold safety factor to account for sensitive humans.

The determination of ADI's is somewhat more complicated for hexazinone and picloram. In the case of hexazinone, the EPA is awaiting the completion of a chronic dog-feeding study. Although a NOEL of 10 mg/kg can be derived from a chronic rat study, the possibility exists that a chronic dog-feeding study could provide a lower maximum NOEL. In the absence of this dog study, the EPA has based the ADI on the NOEL from a 90-day dog-feeding study and a margin of safety of 2,000.

Similarly, for picloram the lifetime ADI was calculated by dividing the 90-day dog-feeding study NOEL of 50 mg/kg by a safety factor of 2,000. The more recent NOEL data reported in this analysis will eventually work its way through the regulatory framework and may result in a higher ADI since less extreme safety factors would be required.

It could be argued that, considering the transient nature of most worst-case doses, an ADI for these doses might be calculated by dividing a subchronic (e.g., 90-day) NOEL by a safety factor of 100. Even the spray applicators are typically involved in spraying for 30 days or less. However, the more conservative lifetime ADI values are provided on Table 2.37.

EPA has not approved the use of amitrole on crops or forage, and thus has not set tolerance limits or ADI's for this compound. The "ADI" provided on Table

2.37 was calculated by dividing the NOEL value of 0.025 by a safety factor of 100.

The ADI's and NOEL's indicate the significance of doses levels determined in Sections 2.1 through 2.4. Section 2.6 will provide a detailed comparison of the dose values and the ADI's and NOEL's.

Table 2.37--Maximum fetotoxicity NOEL for most sensitive species and Acceptable Daily Intake (ADI) values.

| Herbicide | Fetotoxicity NOEL in mg/kg/day | ADI values in mg/kg/day | Reference for ADI |
|---|---|---|---|
| Amitrole | 5 | 0.00025 | USEPA, 1985c[1] |
| Atrazine | 15 | 0.0375 | Fed. Register 12/30/81 p. 63085 |
| 2,4-D | 25 | 0.01 | USEPA, 1985a[1] |
| Dicamba | 3 | 0.0125 | Fed. Register 3/16/83 p. 11119 |
| Glyphosate | 10 | 0.1 | Fed. Register 10/30/85 p. 45121 |
| Hexazinone | 125 | 0.0125 | Fed. Register 8/17/83 p. 37214 |
| Picloram | 500 | 0.0250 | Fed. Register 9/22/82 p. 41770 |

1/ADI calculated by dividing the NOEL from Table 2.36 by a safety factor of 100.

A separate toxicological issue in the use of pesticides involves the possible carcinogenic and mutagenic activity of herbicides. Unlike the general toxic effects of herbicides discussed in this section, this analysis will not assum that there is a dose threshhold below which cancer will not occur. These issues are presented in detail in Section 2.7.

The remainder of Section 2.5 discusses the general toxicity of herbicides as formulated including manufacturing byproducts.

## 2.5.1 Toxicity of Pesticide Formulations

As formulated for field use, pesticide active ingredients are mixed with a variety of compounds typically listed as "inert ingredients" on the label. These ingredients are often comprised of various surfactants, adjuvants, and emulsifiers as needed to increase the usefulness of the pesticide. The chemical identities of these compounds are closely guarded trade secrets.

Environmental Protection Agency requires some toxicity testing of the formulated pesticides to indicate possible human health and environmental impacts of the formulations. Five mammalian tests are required for registration: Acute oral $LD_{50}$, dermal sensitization, eye irritation, dermal $LD_{50}$, and acute inhalation. USDA Handbook 633 (USDA 1984) provides a review of these tests.

Table 2.38 compares the acute oral toxicity of the pesticide active ingredient and the acute oral toxicity of formulations of the pesticide. As indicated by this table, formulated mixtures have comparable or lower acute oral toxicities than the unformulated pesticide active ingredients. Concern has also been expressed about the possible effect of surfactants in herbicide formulations on the absorption of herbicide active ingredients through human skin and the subsequent toxic effects of the herbicides. As indicated on Table 2.39, acute dermal toxicities of the active ingredient and formulated products are similar.

On some toxicity variables, differences are noted between formulations. For example, the Roundup formulation of glyphosate has much higher toxicity to fish than the Rodeo formulation ($LC_{50}$ for trout of 11 parts per million (ppm) for Roundup and greater than 1,000 ppm for Rodeo). These differences are functions of the difference in the toxicity of the surfactants used in the formulation. The more toxic surfactant used in Roundup has no effect on the bioaccumulation of glyphosate in fish.

## 2.5.2 Toxicity of Herbicide Product Impurities

### 2.5.2.1 Dioxins and Phenolics in 2,4-D

The issue of contaminants in herbicides has received much publicity. The most noted case is the incidence of "dioxins", particularly 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) in Agent Orange. Because related compounds have been discovered in 2,4-D, concern has been raised over the possible health effects of these compounds.

Some confusion over possible health effects arises from mistaken terminology, particularly in the use of the terms "dioxin" and "TCDD." A brief digression in chemical nomenclature is warranted prior to discussing the toxicity of these compounds.

The term "dioxin" is most often used to refer to a class of compounds more properly referred to as dibenzo-p-dioxins. From a toxicological standpoint, the dibenzo-p-dioxins of most interest are those which have chlorine attached to one or more of eight positions on the molecule. These compounds can be referred to as chlorodibenzo-p-dioxins. The actual number and location of chlorine molecules will greatly affect the toxicity of the compound. The most infamous and toxic of the chlorodibenzo-p-dioxins is the 2,3,7,8-tetrachloro-

dibenzo-p-dioxin (2,3,7,8-TCDD), a compound with four chlorine atoms located at positions 2,3,7, and 8 on the molecule. Unfortunately all dioxins are often assumed to be similar or identical to 2,3,7,8-TCDD even though each of the approximately 75 chlorodibenzo-p-dioxin compounds varies significantly in its chemical and biological properties.

2,3,7,8-TCDD can be formed under certain conditions from the combination of two molecules of 2,4,5-triclorophenol (a raw material for Agent Orange). In the reaction, each 2,4,5-TCP molecule loses a chlorine atom resulting in formation of the four-chlorine compound 2,3,7,8-TCDD.

Table 2.38--Comparison of the acute oral toxicity of pesticide active ingredients and pesticide formulations.

| Pesticide active ingredient | Oral $LD_{50}$ (mg/kg) | Formulation | Oral $LD_{50}$ (mg/kg) |
|---|---|---|---|
| Amitrole | 1,100 | Amitrole-T | 5,000 |
| Atrazine | 1,400 | AAtrex | 1,750 |
| | | Atrazine, 80W | 5,100 |
| 2,4-D (acid) | 100 | 2,4-D (butyl ester) | 380 |
| | | 2,4-D (sodium salt) | 360 |
| Dicamba | 566 | Banvel Technical | 1,707 |
| | | Banvel DMA | 1,028 |
| Glyphosate | 3,800 | Roundup | 5,400 |
| | | Rodeo | 5,000 |
| Hexazinone | 860 | Hexazinone (66% wettable powder) | 4,495 |
| | | Hexazinone (10% Gridball) | 7,500 |
| | | Hexazinone (20% Gridball) | 5,000 |
| Picloram | 2,000 | Tordon 22K (potassium salt) | 10,300 |
| | | Picloram (isooctyl ester) | 2,830 |

Table 2.39--Comparison of the acute dermal toxicity of pesticide active ingredients and pesticide formulations.

| Pesticide active ingredient | Dermal $LD_{50}$ (mg/kg) | Formulation | Dermal $LD_{50}$ (mg/kg) |
|---|---|---|---|
| Amitrole | >2,500 | Amizol | 10,000 |
| Atrazine | - | AAtrex | 9,300 |
| | | Atrazine, 80W | 5,100 |
| 2,4-D (acid) | 1,400 | 2,4-D (butyl ester) and 2,4-D (dimethyl-amine salt) | No adverse reaction to 3.13% solution applied 5 times weekly for 3 weeks. |
| Dicamba | >2,500 | Banvel Technical | >2,000 |
| | | Banvel DMA | >2,000 |
| Glyphosate | >7,940 | Roundup | >7,940 |
| Hexazinone (90%) | >5,278 | Hexazinone (25% liquid) | >7,500 |
| | | Hexazinone (66% dry flowable) | >2,000 |
| Picloram | >4,000 | Tordon 22K (potassium salt) | >2,000 |

In the production of 2,4-D, an intermediate product is 2,4 dichlorophenol (2,4-DCP). Under some circumstances it is possible to join two molecules of 2,4-DCP to form the two-chlorine compound 2,7-dichlorodibenzo-p-dioxin (2,7-DCDD), a compound which differs only slightly in structure from 2,3,7,8-TCDD, but over a millionfold in toxicity. 2,7-DCDD has been found in three of 30 samples of U.S.-produced 2,4-D along with traces of other relatively nontoxic chlorodioxins with three and four chlorines. The concentrations in the three positive samples ranged from 25 to 60 parts per billion (ppb).

If one were to conservatively assume that all 2,4-D contained 100 ppb 2,7-DCDD, one can calculate the maximum dose of 2,7-DCDD to various exposed individuals. For example, if the maximum expected worker dose of 2,4-D is 0.3 mg/kg, the maximum dose of 2,7-DCDD to the exposed human would be 0.00000003 mg/kg.

Several toxicologic studies of 2,4-DCDD have been reported. Khera and Ruddick (1973) fed DCDD at dosages of 1 and 2 mg/kg daily to determine whether 2,7-DCDD could cause birth defects. The observed effect at 1 mg/kg was a modest degeneration of heart muscle fibers and some fluid accumulation around the heart in a few of the animals. A somewhat greater number of animals were affected at 2 mg/kg. Both effects are in the category of general fetal toxicity. No teratogenic effect was found. The 1 mg/kg dose is about 30 million times greater than the worst-case dose to workers.

The National Cancer Institute (1979) work was carried out by feeding 2,7-DCDD as 0.5 and 1 percent of the total diet for 2 years. The data indicated a "suggested" carcinogenic effect in male mice only that was not strong enough to support a conclusion that DCDD is a carcinogen. Female mice and rats of both sexes did not significantly respond. As will be discussed in Section 2.7, 2,7-DCDD shows less carcinogenic potential than 2,4-D, the herbicide of concern.

Additional concerns have been raised with the presence of 2,4-diclorophenol (2,4-DCP) in 2,4-D. As discussed above, 2,4-DCP is an intermediate product from which 2,4-D is synthesized. The eight manufacturers of 2,4-D in the United States have analyzed their products for 2,4-DCP. Total chlorphenols, of which 2,4-DCP is predominant, comprise about 0.3 percent of the product in the most contaminated sample. Other chlorophenols include 2,6-DCP and 2-chlorophenol and 4-chlorophenol, all of which are minor contributors. Many products contained no detectable chlorophenols.

2,4-DCP and other chlorophenols have very high vapor pressures and thus evaporate quickly. Microbial degradation of chlorophenols occurs more quickly than degradation of 2,4-D and thus accumulation in the environment is impossible (Verschueren 1983). Chlorophenols are also naturally occurring compounds. For example, 2,6-DCP is a pheromone of the lone star tick, Amblyomma americanum.

The toxicity of 2,4-DCP is extremely low. Chronic (6 months) treatment of mice, at 0.1 percent (1,000 ppm) of total diet, produced no effects other than a slight liver enlargement (Kobayaski et al. 1972). The lethal dose is on the order of 10 times greater than that of 2,4-D.

### 2.5.2.2 Nitrosoamine Formation from Glyphosate

The reaction of secondary amines such as glyphosate with nitrite ions to form various nitrosoamines has received much attention. Testing has shown as many as 70 to 80 percent of nitrosoamines are carcinogenic in animals tests. The formation of N-nitrosoglyphosate (NNG) has been documented (Khan and Young 1977). However, NNG levels in formulated herbicide products are less than 0.1 part per million (Saunders 1985) and NNG has not been detected in raw agricultural products (USEPA 1978).

An additional concern has been possible formation of NNG inside the human body throughout the reaction of nitrates in saliva and stomach fluids with glyphosate. Monsanto has reported tests of the carcinogenicity of NNG compound in mammals (Monsanto 1984). However, the validity of these tests by Industrial Bio-Test (IBT) is questionable due to numerous testing irregularities (Saunders 1985).

Although direct tests of NNG are not available, the indirect testing of possible health effects of NNG is accomplished through animal feeding studies. Rats, in particular, would be prone to *in vivo* nitrosoamine formation because their stomach pH of 2.5 to 3.5 is more conducive to nitrosoamine formation than that of humans whose stomach pH is in the range of 1.5. The kinetics of nitrosamine formation are discussed extensively in an article by Mirvish (1975).

The carcinogenic potential of glyphosate and NNG based on high-dose feeding studies is discussed further in Section 2.7.

## 2.6 DOSE/TOXICITY LEVEL COMPARISONS

In this risk analysis, the dose to a hypothetical, maximum-exposed individual is compared to the NOEL and ADI values for the herbicide in question. The maximum-exposed resident near open-range projects is assumed to receive a direct dose from drifting herbicides as well as an oral dose from the consumption of contaminated vegetables and beef. The maximum-exposed residents in the right-of-way scenario is assumed to receive a direct dose from drift and oral doses from drinking 2 liters of contaminated water and eating contaminated vegetables and fish (or beef). Consumption of beef instead of fish would lower the overall dose (see Tables 2.32, 2.33, and 2.34).

The maximum-exposed visitor to an open-range project is assumed to spend the day on site and to eat contaminated wild food.

There exists a small possibility that a worker would not only be exposed to worst-case levels on the job, but would also live near a spray site and be dosed through consumption of drift-contaminated vegetables or beef. However, even with the considerable overestimation of the exposure and dose levels in these residential dose pathways, the incremental impact on a worst-case worker would be negligible. For example, the worst-case dose (including major mixing errors) to a worker on a mid-sized project using 2,4-D would be raised from 0.85 mg/kg/day to 0.854 mg/kg/day if the worker also ate contaminated beef and vegetables as a resident near such projects.

Tables 2.40 through 2.72 provide comparisons of the worst-case dose to workers and maximum-exposed residents and visitors with the NOEL values and the ADI values for each herbicide. The entry in each matrix element is the number by which a dose would have to be multiplied in order to equal the NOEL or the ADI. For example, the NOEL comparison factor of 390 for an adult resident in the vicinity of a small, open-range project sprayed with 2,4-D (see Table 2.41) was calculated by dividing the NOEL value for 2,4-D (from Table 2.36) by the sum of the adult resident doses from Table 2.9 ((1.0 mg/kg/day)/((5 x $10^{-5}$ + 7.1 x $10^{-4}$ + 1.8 x $10^{-3}$) mg/kg/day)).

The safety factors provided on Tables 2.40 through 2.72 are for the days of maximum exposure which is generally the day of spraying. Since the direct dose from drift will only occur on the day of exposure, the comparison factors for subsequent days involving only oral doses would be higher, though often only slightly. In those cases where there is a marked contrast between dose on the first day and carryover doses on subsequent days, two separate entries on the dose comparison tables are made. For example, the hypothetical adolescent who wanders very close to the spray site would receive a relatively high direct dose for a short period of time on the day of spraying. Maximum indirect doses on subsequent days would be much less. Thus, Tables 2.67 through 2.72 contain an entry that represents the safety factor for dermal and oral doses to this adolescent on the first day and a separate entry for doses on subsequent days. Separate entries are also made on these tables for visitors who merely enter sprayed areas and for visitors who both enter a sprayed area and consume wild foods that have been sprayed.

Table 2.40--NOEL/dose comparisons for workers on small, open-range projects.[1]

| | Worker - minor mixing error | Worker - major mixing error |
|---|---|---|
| 2,4-D | 2.7 | 2.4 |
| Picloram | 39 | 33 |
| 2,4-D/Picloram | 5.5/140 | 4.8/117 |
| 2,4-D/Dicamba | 4.5/11 | 3.8/10 |
| Dicamba | 7 | 6 |
| Glyphosate | 56 | 48 |
| Amitrole | Above[2] | Above[2] |
| Atrazine | 10 | 8.7 |
| Hexazinone | 27 | 23 |

[1]All worst-case worker doses are above ADI values.

[2]Worker dose above NOEL level.

Table 2.41--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with 2,4-D.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 390 | 3.9 | 325 | 3.2 |
| Adolescent resident | 388 | 3.9 | 323 | 3.2 |
| Infant resident | 317 | 3.2 | 271 | 2.7 |
| Visitor re-entry | 12,820 | 128 | 10,417 | 104 |
| Visitor re-entry with consumption of sprayed wild food | 18 | Above[1] | 14 | Above |

[1]Dose is above the ADI.

Table 2.42--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with picloram.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 4,368 | 16 | 3,860 | 14 |
| Adolescent resident | 4,366 | 16 | 3,858 | 14 |
| Infant resident | 3,615 | 13 | 3,130 | 11 |
| Visitor re-entry | 179,490 | 641 | 145,830 | 520 |
| Visitor re-entry with consumption of sprayed wild food | 249 | Above[1] | 203 | Above[1] |

[1]Dose is above the ADI.

Table 2.43--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with dicamba.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 769 | 7.7 | 679 | 6.8 |
| Adolescent resident | 765 | 7.6 | 675 | 6.7 |
| Infant resident | 628 | 6.3 | 542 | 5.4 |
| Visitor re-entry | 32,050 | 320 | 26,040 | 260 |
| Visitor re-entry with consumption of sprayed wild food | 45 | Above[1] | 37 | Above[1] |

[1]Dose is above the ADI.

Table 2.44--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with glyphosate.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 6,154 | 62 | 5,428 | 54 |
| Adolescent resident | 6,120 | 61 | 5,400 | 54 |
| Infant resident | 5,024 | 50 | 4,388 | 43 |
| Visitor re-entry | 256,410 | 2,564 | 208,330 | 2,080 |
| Visitor re-entry with consumption of sprayed wild food | 357 | 4 | 294 | 3 |

Table 2.45--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with 2,4-D/picloram.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 615/7,138 | 6.2/25 | 542/7,135 | 5.4/25 |
| Adolescent resident | 612/7,134 | 6.1/25 | 540/7,134 | 5.4/25 |
| Infant resident | 502/6,354 | 5.0/22 | 443/5,923 | 4.3/21 |
| Visitor re-entry | 25,640/700,000 | 256/2,500 | 20,830/583,000 | 208/2,080 |
| Visitor re-entry with consumption of sprayed wild food | 428/1,000 | Above[1]/4 | 29/820 | Above/3 |

[1]Dose is above the ADI.

Table 2.46--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with 2,4-D/dicamba.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 543/996 | 5.4/10 | 488/920 | 4.8/9.2 |
| Adolescent resident | 540/993 | 5.4/10 | 485/917 | 4.8/9.2 |
| Infant resident | 434/800 | 4.5/8.0 | 367/711 | 3.7/7.1 |
| Visitor re-entry | 20,800/52,000 | 208/520 | 16,660/41,660 | 166/417 |
| Visitor re-entry with consumption of sprayed wild food | 29/73 | Above[1] | 24/60 | Above[1] |

[1]Dose is above the ADI.

Table 2.47--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with amitrole.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 16 | Above[1] | 14 | Above |
| Adolescent resident | 16 | Above | 14 | Above |
| Infant resident | 13 | Above | 12 | Above |
| Visitor re-entry | 641 | 6 | 520 | 5 |
| Visitor re-entry with consumption of sprayed wild food | Equal[2] | Above | Above | Above |

[1]Dose is above the ADI.

[2]Dose is approximately equal to the NOEL.

Table 2.48--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with hexazinone.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 6,060 | 7.6 | 5,339 | 6.7 |
| Adolescent resident | 6,010 | 7.5 | 5,296 | 6.6 |
| Infant resident | 4,878 | 6.1 | 4,200 | 5.3 |
| Visitor re-entry | 128,200 | 1,282 | 104,167 | 130 |
| Visitor re-entry with consumption of sprayed wild food | 357 | Above[1] | 294 | Above[1] |

[1]Dose is above the ADI.

Table 2.49--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a small, open-range project sprayed with atrazine.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 466 | 4.7 | 454 | 4.5 |
| Adolescent resident | 464 | 4.6 | 452 | 4.5 |
| Infant resident | 394 | 3.9 | 381 | 3.8 |
| Visitor re-entry | 48,077 | 481 | 39,062 | 390 |
| Visitor re-entry with consumption of sprayed wild food | 134 | 1.3 | 110 | 1.1 |

Table 2.50--NOEL/dose[1] comparisons for workers on mid-sized, open-range projects.

| | Minor mixing error | Major mixing error |
|---|---|---|
| | NOEL | NOEL |
| 2,4-D | 1.2 | 1.2 |
| Picloram | 17 | 17 |
| Dicamba | 3 | 3 |
| 2,4-D/Picloram | 2.5/64 | 2.3/58 |
| 2,4-D/Dicamba | 2.0/5 | 1.9/5 |
| Glyphosate | 25 | 24 |
| Amitrole | Above[2] | Above[2] |
| Atrazine | 4.7 | 4.4 |
| Hexazinone | 12 | 12 |

[1]All worker doses are above the ADI's.

[2]Dose is above the NOEL.

Table 2.51--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with 2,4-D.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 257 | 2.6 | 212 | 2.1 |
| Adolescent resident | 255 | 2.5 | 210 | 2.1 |
| Infant resident | 207 | 2.1 | 173 | 1.7 |
| Visitor re-entry | 1,960 | 20 | 1,587 | 16 |
| Visitor re-entry with consumption of sprayed wild food | 17 | Above[1] | 15 | Above[1] |

[1]Dose is above the ADI.

Table 2.52--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with picloram.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 3,161 | 11 | 2,677 | 9.6 |
| Adolescent resident | 3,159 | 11 | 2,676 | 9.6 |
| Infant resident | 2,555 | 9.1 | 2,159 | 7.7 |
| Visitor re-entry | 26,920 | 269 | 21,875 | 78 |
| Visitor re-entry with consumption of sprayed wild food | 250 | Above[1] | 206 | Above |

[1]Dose is above the ADI.

Table 2.53--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with dicamba.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 555 | 5.6 | 469 | 4.7 |
| Adolescent resident | 552 | 5.5 | 467 | 4.7 |
| Infant resident | 442 | 4.4 | 373 | 3.7 |
| Visitor re-entry | 4,808 | 48 | 3,906 | 39 |
| Visitor re-entry with consumption of sprayed wild food | 45 | Above | 3.7 | Above |

Table 2.54--Worst-case NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with glyphosate.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 4,442 | 44 | 3,759 | 38 |
| Adolescent resident | 4,419 | 44 | 3,740 | 37 |
| Infant resident | 3,536 | 35 | 3,000 | 30 |
| Visitor re-entry | 38,460 | 385 | 31,250 | 312 |
| Visitor re-entry with consumption of sprayed wild food | 357 | 3.6 | 294 | 2.9 |

Table 2.55--NOEL/dose and ADI/dose for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with 2,4-D/picloram.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 444/6,300 | 4.4/22 | 376/5,779 | 3.8/21 |
| Adolescent resident | 441/6,297 | 4.4/22 | 374/5,775 | 3.7/21 |
| Infant resident | 353/5,250 | 3.6/19 | 300/4,870 | 3.0/17 |
| Visitor re-entry | 3,846/107,690 | 38/385 | 3,125/87,500 | 31/312 |
| Visitor re-entry with consumption of sprayed wild food | 428/1,000 | 4.3/3.6 | 353/824 | 3.5/2.9 |

Table 2.56--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with 2,4-D/dicamba.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 376/742 | 3.8/7.4 | 337/679 | 3.4/6.8 |
| Adolescent resident | 374/739 | 3.7/7.4 | 334/675 | 3.3/6.7 |
| Infant resident | 298/598 | 3.0/6.0 | 244/520 | 2.4/5.2 |
| Visitor re-entry | 3,125/7,812 | 31/78 | 2,500/6,250 | 25/62 |
| Visitor re-entry with consumption of sprayed wild food | 29/74 | Above[1] | 24/60 | Above |

[1]Doses are above the ADI.

Table 2.57--NOEL/dose and ADI dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with amitrole.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 11 | Above | 9.6 | Above |
| Adolescent resident | 11 | Above | 9.6 | Above |
| Infant resident | 9.1 | Above | 8.2 | Above |
| Visitor re-entry | 96 | 1 | 78 | Above |
| Visitor re-entry with consumption of sprayed wild food | Equal[1] | Above[2] | Above | Above |

[1]Dose is approximately equal to the NOEL.

[2]Dose is above the ADI.

Table 2.58--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with hexazinone.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 4,361 | 5.4 | 3,690 | 4.6 |
| Adolescent resident | 4,320 | 5.4 | 3,650 | 4.6 |
| Infant resident | 3,410 | 4.2 | 2,873 | 3.6 |
| Visitor re-entry | 19,600 | 24 | 15,870 | 20 |
| Visitor re-entry with consumption of sprayed wild food | 357 | Above[1] | 294 | Above |

[1]Dose is above the ADI.

Table 2.59--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a mid-sized, open-range project sprayed with atrazine.

| | Minor mixing error | | Major mixing error | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 432 | 4.3 | 412 | 4.1 |
| Adolescent resident | 430 | 4.3 | 410 | 4.1 |
| Infant resident | 360 | 3.6 | 342 | 3.4 |
| Visitor re-entry | 7,211 | 72 | 5,952 | 60 |
| Visitor re-entry with consumption of sprayed wild food | 134 | 1.3 | 110 | 1.1 |

Table 2.60--NOEL/dose and ADI/dose comparisons for backpack sprayers on large, open-range projects.[1]

| | Minor mixing errors | Major mixing errors |
|---|---|---|
| 2,4-D | 1.2 | 1.2 |
| Picloram | 18 | 18 |
| Dicamba | 3.1 | 2.9 |
| 2,4-D/Picloram | 2.5/70 | 2.3/63 |
| 2,4-D/Dicamba | 2.0/5.2 | 1.9/4.8 |
| Glyphosate | 25 | 23 |
| Amitrole | Above[2] | Above[2] |
| Atrazine | 4.7 | 4.4 |
| Hexazinone | 12 | 12 |

[1]All worker doses are above the ADI.

[2]Dose is above the NOEL.

Table 2.61--NOEL/dose and ADI/dose comparisons for truck drivers and supervisors on large, open-range projects.

| | Supervisor | | Truck driver | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| 2,4-D | 125 | 1.2 | 1.5 | Above[1] |
| Picloram | 1,750 | 6 | 21 | Above |
| Dicamba | 312 | 1.2 | 1.5 | Above |
| 2,4-D/picloram | 250/6,363 | 2.5/23 | 3.0/88 | Above |
| 2,4-D/dicamba | 204/521 | 2.0/5.2 | 2.5/6.2 | Above |
| Glyphosate | 2,500 | 25 | 30 | Above |
| Amitrole | 6 | Above | Above | Above |
| Atrazine | 463 | 5 | 5.7 | Above |
| Hexazinone | 1,235 | 1.6 | 4 | Above |

[1]Doses are above the ADI.

Table 2.62--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with 2,4-D or picloram.

| | 2,4-D | | Picloram | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 95 | Above[1] | 1,224 | 4.4 |
| Adolescent resident | 94 | Above | 1,223 | 4.4 |
| Infant resident | 75 | Above | 992 | 3.5 |
| Visitor re-entry | 125 | 1.2 | 7,750 | 6.2 |
| Visitor re-entry with consumption of sprayed wild food | 18 | Above | 250 | Above |

[1]Dose is above the ADI.

Table 2.63--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with glyphosate or dicamba.

| | Glyphosate | | Dicamba | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 1,780 | 18 | 222 | 2.2 |
| Adolescent resident | 1,766 | 18 | 220 | 2.2 |
| Infant resident | 1,370 | 14 | 171 | 1.7 |
| Visitor re-entry | 2,500 | 25 | 312 | 3.1 |
| Visitor re-entry with consumption of sprayed wild food | 357 | 3.6 | 45 | Above |

Table 2.64--NOEL/dose and ADI/dose comparison for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with 2,4-D/picloram or 2,4-D/dicamba.

| | 2,4-D/picloram | | 2,4-D/dicamba | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 178/3,659 | 1.8/13 | 142/322 | 1.4/3.2 |
| Adolescent resident | 177/3,657 | 1.8/13 | 141/320 | 1.4/3.2 |
| Infant resident | 137/2,872 | 1.4/10 | 114/260 | 1.1/2.6 |
| Visitor re-entry | 250/6,363 | 2.5/23 | 204/521 | 2.0/5.2 |
| Visitor re-entry with consumption of sprayed wild food | 36/1,000 | Above/ 3.6 | 29/74 | Above |

Table 2.65--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with amitrole or atrazine.

| | Amitrole | | Atrazine | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 4.5 | Above | 309 | 3.0 |
| Adolescent resident | 4.5 | Above | 307 | 3.0 |
| Infant resident | 3.5 | Above | 249 | 2.5 |
| Visitor re-entry | 6.2 | Above | 469 | 4.7 |
| Visitor re-entry with consumption of sprayed wild food | Above | Above | 134 | 1.3 |

Table 2.66--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of a large, open-range project sprayed with hexazinone.

| | NOEL | ADI |
|---|---|---|
| Adult resident | 1,745 | 2.2 |
| Adolescent resident | 1,721 | 2.2 |
| Infant resident | 1,321 | 1.7 |
| Visitor re-entry | 1,250 | 1.6 |
| Visitor re-entry with consumption of sprayed wild food | 357 | Above[1] |

[1]Dose is above the ADI.

Table 2.67--Dose comparisons for workers on right-of-way projects.

| | Truck driver | | Spot sprayer | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| 2,4-D | 6.2 | Above[1] | 1.2 | Above |
| Picloram | 88 | Above | 18 | Above |
| Dicamba | 16 | Above | 3.1 | Above |
| 2,4-D/picloram | 12/350 | Above/1.2 | 2.5/70 | Above |
| 2,4-D/dicamba | 10/25 | Above | 2.0/5.2 | Above |
| Glyphosate | 125 | 1.2 | 25 | Above |
| Amitrole | Above[2] | Above | Above | Above |
| Atrazine | 23 | Above | 4.7 | Above |
| Hexazinone | 62 | Above | 12 | Above |

[1]Worker dose is above the ADI.

[2]Dose is above the NOEL.

Table 2.68--NOEL/dose and ADI/dose comparisons for maximum exposed residents and visitors in the vicinity of right-of-way projects sprayed with 2,4-D or picloram.

| | 2,4-D | | Picloram | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 144 | 1.4 | 2,023 | 7.2 |
| Adolescent resident (dermal and oral dose) | 21 | Above[1] | 1,119 | 4.0 |
| Adolescent resident (oral doses only) | 114 | 1.1 | 1,606 | 5.7 |
| Infant resident | 101 | 1.0 | 1,425 | 5.1 |
| Visitor re-entry | 568 | 5.7 | 7,954 | 28 |

[1]Dose is above the ADI.

Table 2.69--NOEL/dose and ADI/dose comparison for maximum-exposed residents in the vicinity of right-of-way projects sprayed with dicamba or glyphosate.

| | Dicamba | | Glyphosate | |
|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI |
| Adult resident | 359 | 3.6 | 2,875 | 29 |
| Adolescent resident (dermal and oral dose) | 55 | Above | 445 | 4 |
| Adolescent resident (oral doses only) | 361 | 3.6 | 2,891 | 29 |
| Infant resident | 249 | 2.5 | 1,104 | 11 |
| Visitor re-entry | 1,420 | 14 | 11,363 | 114 |

Table 2.70--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with 2,4-D/picloram mixtures.

| | 2,4-D/picloram | |
|---|---|---|
| | NOEL | ADI |
| Adult resident | 287/8,088 | 2.8/29 |
| Adolescent resident (dermal and oral dose) | 42/4,250 | Above/15 |
| Adolescent resident (oral doses only) | 229/6,100 | 2.3/22 |
| Infant resident | 200/5,982 | 2/21 |
| Visitor re-entry | 1,136/30,435 | 11/109 |

Table 2.71--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with 2,4-D/dicamba mixtures.

| | 2,4-D/dicamba | |
|---|---|---|
| | NOEL | ADI |
| Adult resident | 232/580 | 2.3/5.8 |
| Adolescent resident | 35/88 | Above[1] |
| Adolescent resident (oral dose only) | 234/583 | 2.3/5.8 |
| Infant resident | 166/421 | 1.7/4.2 |
| Visitor re-entry | 909/2,500 | 9/25 |

[1]Dose is above the ADI.

Table 2.72--NOEL/dose and ADI/dose comparisons for maximum-exposed residents and visitors in the vicinity of right-of-way projects sprayed with amitrole, atrazine, or hexazinone.

| | Amitrole | | Atrazine | | Hexazinone | |
|---|---|---|---|---|---|---|
| | NOEL | ADI | NOEL | ADI | NOEL | ADI |
| Adult resident | 7.2 | Above[1] | 1,016 | Above | 2,710 | 3.4 |
| Adolescent resident (dermal and oral doses) | 4.0 | Above | 80 | Above | 235 | Above |
| Adolescent resident (oral doses) | 5.7 | Above | 824 | 8.2 | 2,200 | 2.7 |
| Infant resident | 5.1 | Above | 718 | 7.1 | 1,914 | 2.4 |
| Visitor re-entry | 28 | Above | 2,131 | 21 | 5,682 | 7.1 |

[1]Dose is above the ADI.

## 2.6.1 Discussion of ADI and NOEL Comparisons for the General Population Doses

In reviewing the dose/NOEL comparison on Tables 2.40 through 2.72, several patterns are noteworthy. With but few exceptions discussed below, the worst-case doses to maximum-exposed members of the general population are all below ADI values. From the standpoint of general toxic effects (noncarcinogenic), a dose can be considered safe if it is below the ADI. The converse is not necessarily true, that is doses above the ADI are not necessarily harmful. The ADI presumes a daily dose everyday for a lifetime, and higher short-term doses can often be tolerated safely.

Amitrole use provides the most potential for adverse human impacts. Many general population doses exceed the ADI and are close to the dose levels which disrupt thyroid function in test animals. Careful site specific analysis would be needed for any proposed use of this herbicide. The remainder of this section discusses other situations in which the dose could exceed the ADI for various herbicides.

The dose comparisons show that the dose to a visitor to National Forest System lands could exceed the ADI's if he or she collects and consumes a large quantity of sprayed, unwashed vegetation. For numerous reasons there is a very low probability of this event. Very little land is actually being sprayed for noxious weeds (less than 0.04 percent of National Forest land per year in Region 1). Areas that are sprayed are not the places that visitors go to collect wild foods. The vegetation which is the target (knapweed, leafy spurge, thistle, etc.) is not edible, and berry bushes and other prime wild food plants generally do not occupy the habitats that are infested with noxious weeds. Finally, the appearance, odor, and taste of the sprayed vegetation would significantly reduce palatability of wild foods. At concentrations above 5 to 10 mg/kg (parts per million) on food, 2,4-D, picloram, and dicamba impart

a bitter taste to food. Notwithstanding these consumption limiting factors, the calculated doses indicate that even if these improbable events were realized, adverse health impacts would be highly unlikely with such a transient dose.

The maximum estimated dose to an adolescent who stands within 1 meter (3 feet) of a right-of-way spray project could exceed the ADI for the herbicides atrazine, 2,4-D, dicamba, and hexazinone. As discussed in Section 2.4.4, this maximum estimate is about 5 times higher than a dose estimate based on extrapolations from actual measurements of project supervisors' doses and none of these more reasonable dose estimates exceed the ADI. Even the maximum dose estimates provide NOEL margins of safety of 20 or greater. For example, the dicamba NOEL is over 50 times greater than the dose, and the hexazinone NOEL is over 230 times greater than the dose. Because the NOEL and ADI presume long-term exposure, adverse impacts from this one-time dose are very unlikely. As discussed in Section 2.5, the hexazinone ADI is based on a NOEL from a 90-day feeding study divided by a safety factor of 2,000. A safety factor of 235 for the one-time dose of hexazinone indicates very little risk. Short-term tests with dicamba reveal a similar pattern. A 13-week feeding study with rats indicated a NOEL of 25 mg/kg (500 ppm in food) in contrast to a 2-year NOEL of 1.25 mg/kg. A one-time dicamba dose of 0.019 mg/kg is very unlikely to cause adverse health impacts since the dose is approximately 1,300 times less than the 13-week NOEL.

Large, open-range projects sprayed with 2,4-D in excess of 2 pounds (a.i.) per acre could result in a combination of doses to maximum-exposed individuals that would slightly exceed the ADI for 2,4-D. In the scenario outlined in Section 2.3, the largest dose comes from the consumption of drift-contaminated vegetables from a garden located within 220 yards of the spray site. Site-specific analysis of such large projects will indicate whether this scenario is realistic.

### 2.6.2 Discussion of ADI and NOEL Comparisons for Worker Doses

Many worst-case worker doses calculated in this analysis exceed EPA's ADI values. All workers involved in the direct hand application of liquid formulation could receive worst-case doses in excess of ADI values. In reaching conclusions on the relevance of these findings, it is appropriate to consider several factors.

First, several worst-case assumptions serve to increase estimates of worker dose. For example, it is assumed that dose is a direct linear function of the amount applied. Thus, if a backpack applicator applies twice the amount in a day as the applicators in the worker exposure study (Lavy et al. 1984), then it is assumed that the applicator's dose will be twice the baseline dose. This relationship is open to question since in Lavy's study backpack sprayers were often saturated with herbicide mix although these workers generally sprayed less active ingredient in a day than assumed here. As discussed in Section 2.4.1, it is possible that they received a maximum dose and that spraying additional active ingredient in a work day would have no effect on dose.

As noted throughout this document, in the absence of readily attainable data on specific parameters very conservative (i.e., worst-case) assumptions were made that tend to overestimate dose. Less conservative and more realistic assumptions will provide lower dose estimates and increase the margin of safety.

Table 2.73 compares various estimates of worker dose for backpack sprayers. The worst-case NOEL/dose comparisons on Table 2.73 are those developed above in Section 2.6. The high-dose comparisons use the highest dose values measured by Lavy et al. (1984) without extrapolations based on differences in daily application amount. As discussed in Section 2.4.1, workers in the Lavy study applied herbicides under conditions that are likely to maximize worker dose. The high dose probably approximates doses to workers who apply large quantities of herbicide in a day with careless techniques, little protective clothing, and high oral intakes due to secondary contamination of cigarettes, lunches, etc. The average-dose comparisons on Table 2.73 correspond to the average worker doses measured in Lavy et al. (1984).

The margins of safety for average workers as indicated by the NOEL/dose comparisons are greater than 10 for all herbicides except amitrole. These margins of safety (excepting amitrole) are probably sufficient to protect the average worker from general toxic effects such as kidney or liver dysfunction. These margins of safety are placed in a better light by considering the worker's typically limited extent of exposure (usually less than 30 days per year).

Higher doses are typically tolerated over shorter periods of time. For example, although dicamba shows relatively low margins of safety when comparing worker doses to long-term dose tests, short-term tests with dicamba indicate higher tolerance levels. No effects were noted at 7 weeks in rats fed dicamba at the highest levels tested (50 mg/kg). At 13 weeks, rats show histological changes in the liver at 40 mg/kg but not at 25 mg/kg/. A similar pattern would probably be evidenced in dogs which are relatively sensitive to organic acids. The dicamba NOEL of 1.25 mg/kg used in this document is based on a 2-year feeding study with dogs.

Careless work habits and poor application techniques could result in worker doses with low margins of safety particularly with the herbicides 2,4-D and dicamba. At worker doses approaching the high or worst-case dose levels used in the comparisons in Table 2.74, possible liver and kidney anomalies could result from continued exposure (perhaps as low as 60 days) although these effects are typically reversible. For example, the kidney effects noted with 2,4-D at the lowest effect levels are reversible with cessation of dose even after 60 to 90 days of continuous exposure.

A second area of concern with higher dicamba doses is the possibility of fetotoxic or teratogenic effects. As discussed in Section 2.5, the fetotoxic NOEL is 3 mg/kg for dicamba and the teratogenic NOEL is 10 mg/kg. At the worst-case worker dose levels calculated in this analysis, it is not possible to offer assurances that the teratogenic effects of dicamba exposure can be avoided by reducing the length of time of herbicide exposure. It has been shown that many teratogens operate during relatively short time frames or critical periods in pregnancy. These periods generally occur in the early stages of pregnancy, often before pregnancy is confirmed. Thus, it is not the absolute length of exposure that is relevant, but its timing relative to the critical period. Therefore, because of the low teratogenicity margins of safety for workers spraying dicamba, restrictions on the use of women as herbicide applicators are advisable.

Margins of safety for fetotoxic and teratogenic effects for 2,4-D doses are considerably higher. Fetotoxic NOEL for 2,4-D is 25 mg/kg. Teratogenic effects were not seen at the highest doses tested.

Table 2.73--NOEL/dose comparisons for backpack sprayers using worst-case estimates, high-dose estimates, and average-dose estimates.

| | Worst-case worker dose comparisons | High-dose worker dose comparison | Average-dose worker dose comparison |
|---|---|---|---|
| 2,4-D | 1.2 | 4.2 | 11 |
| Picloram | 16 | 29 | 75 |
| Dicamba | 2.9 | 5.1 | 13 |
| 2,4-D/picloram | 2.3/63 | 4.2/29 | 11/75 |
| 2,4-D/dicamba | 1.9/4.8 | 4.2/5.1 | 11/13 |
| Glyphosate | 23 | 41 | 107 |
| Amitrole | Above[1] | Above | Above |
| Atrazine | 4.4 | 15 | 40 |
| Hexazinone | 12 | 41 | 107 |

[1]Dose is above the NOEL.

Toxicity data for atrazine indicates a pattern similar to dicamba although margins of safety are higher. At the lowest dose levels causing effects, in animal tests, the liver is the site of toxic effects. Fetotoxicity/teratogenic effects are seen in animal tests at levels as low as 15 mg/kg. Use patterns on specific projects will determine the level and significance of worker doses. At the application rates assumed here for some types of workers, margins of safety as low as 20 are possible for fetotoxic effects. At the present time, atrazine is not proposed for use on Region 1 national forests.

Amitrole applications provide the greatest potential for adverse health impacts to workers. Careful site specific analysis would be required for any proposed use. At the present time amitrole use is not proposed in Region 1 although it has been used in other Regions.

Toxicity data for glyphosate, hexazinone, and picloram indicate higher margins of safety. Site-specific analysis will indicate more closely the worst-case doses and margins of safety for maximum-exposed workers. For picloram, hexazinone and glyphosate, fetotoxic margins of safety for workers range from about 50 to over 500.

Several management constraints and mitigating activities can be recommended to reduce worker dose and possible health effects.

First, all workers must be advised explicitly of the hazards of these chemicals and instructed in the careful herbicide application techniques so as to reduce dose levels below worst-case values assumed here. Several studies have shown that work practices greatly effect worker exposure and dose.

Second, for some herbicides, such as 2,4-D and dicamba, restrictions on the amount of herbicide applied daily may be necessary for workers subject to higher exposure (e.g., backpack sprayers). Alternatively, application methods resulting in lower exposure to workers may be used. For example, use of trucks or tractors equipped with boom sprayers could be used in some areas. For workers in high-exposure occupations, such as backpack sprayers, application days should be limited to 30 days in a year for 2,4-D or dicamba.

Third, restrictions on the use of women as applicators are advisable for some herbicides. For example, because of the low teratogenicity margins of safety for workers spraying dicamba, restrictions on the use of women of child-bearing age as herbicide applicators may be necessary. These restrictions should be made on a site-specific basis depending on the projected worst-case worker dose and the toxicity data of the herbicide.

## 2.7 PROBABILITIES OF IRREVERSIBLE IMPACTS

To evaluate the ability of the herbicides to produce genotoxic effects such as tumor initiation or heritable mutations, NOELs or thresholds doses are not used. Thresholds are not assumed because it is conceivable that only one or a few molecules of an active chemical may cause certain types of changes in DNA that could form neoplastically transformed cells (cancer) or heritable mutagenic effects (birth defects).

In the case of cancer, individual and population risks can be quantified using various models if there is scientific evidence to suggest a chemical is a carcinogen. Since quantitative risk models are not available for mutagenicity, a multi-step process of evaluating a pesticide's ability to cause mutations and to interact with germinal cells (cells involved in reproduction) is used to assess the qualitative potential of mutagenic risk in humans (see, for example, USEPA 1984a). The first step involves an analysis of the evidence of a pesticide's ability to cause mutations in bacteria, microorganisms, insects, plants, mammalian cells in culture and germinal cells in whole animals; while the second step involves an analysis of its ability to produce these events in mammalian gonads. Greater weight is placed on tests that show changes in germinal cells and tissues than in somatic cells, on tests performed in vivo (within the body) rather than in vitro (outside the body), and in mammalian species rather than in submammalian species (USEPA 1984b). Table 2.74, provided by Dr. David Brusick with Litton Bionetics, Inc., presents a listing of various tests and their value in predicting a chemical's mammalian carcinogenic and heritable mutagenic potential.

Most significant in determining mammalian carcinogenic and heritable mutagenic potential are long-term feeding studies. Single generation feeding studies can determine the carcinogenic potential while multigenerational feeding studies can define the potential for reproductive disruption. However, because a wider variety of cellular systems can be tested in an economical and timely fashion, the tiered mutagenesis testing routine outlined above provides a useful screening system.

The mutagenesis testing results are reviewed below for the herbicides of interest. In reviewing these results, the trends are most significant since no individual mutagenesis test is perfectly predictive and every test can give false positives and false negatives.

Extensive reviews of the mutagenesis literature for the herbicides of interest are provided in Agriculture Handbook 633 (USDA 1984). Highlights of these reviews and the EPA mutagenesis data summaries provided in tolerance determinations are reported below.

### 2.7.1 Amitrole Mutagenesis Tests

Amitrole tested negative (no mutation) in 49 tests with various strains of Salmonella typhimurium in Ames mutagenicity assays. Amitrole was negative in tests with the Chinese hamster ovary (CHO test is indicative of heritable mutagenic potential). Amitrole was nonmutagenic (negative results) in tests with human lymphocytes and various mouse cellular systems.

Table 2.74--A summary of the possible roles for selected short-term tests in chemical hazard assessment.

| General assay type | Identifies carcinogenic potential | Identifies heritable mutagenic potential |
|---|---|---|
| **Microbial Assays** | | |
| Ames Reverse Mutation Test | ++ | + |
| Reverse Mutation in *E. coli* $WP_2$ and Related Strains | + | + |
| Bacterial DNA Repair Tests | + | NA |
| Yeast Mutation Tests | + | ++ |
| Yeast Mitotic Recombination | + | NA |
| **In Vitro Mammalian Cell Assays** | | |
| Mouse Lymphoma Assay (TK) | + | ++ |
| CHO or V79 Mutation Assays (HGPRT) | + | ++ |
| Unscheduled DNA Synthesis (UDS) | ++ | NA |
| Chromosome Aberrations | + | ++ |
| Sister Chromatid Exchange (SCE) | ++ | NA |
| Cell Transformation | ++ | NA |
| **In Vivo Mammalian Assays** | | |
| SCE | + | NA |
| Dominant Lethal Assay | NA | ++ |
| Cytogenetic Analysis (aberrations) | + | ++ |
| Micronucleus Assay | + | + |
| Spermhead Abnormality Assay | NA | (+) |
| Heritable Translocation Assay in Mice | NA | + |
| Specific Locus Assay in Mice | NA | ++ |
| DNA Adduct Formation | + | (+) |
| UDS Assays | + | (+) |
| **In Vivo Submammalian Assays** | | |
| Drosophila Assays | + | ++ |
| Plant Cytogenetics | NA | (+) |

\+ = Applicable
++ = Greater applicability for this role
NA = Not applicable
(+) = Possible application under limited conditions.

(Source: Dr. David J. Brusick, Litton Bionetics, Inc.)

Amitrole tested positive when treated with equimolar amounts of nitrite, indicating that amitrole can be nitrosated to a mutagenic compound. Similar tests with a metabolically activated amitrole also gave positive results for mutagenesis. Amitrole also appears to damage DNA as evidenced by positive responses for unscheduled DNA synthesis observed in HeLa cells and EUE cells. Test evidence does not indicate that amitrole can cause heritable mutations. However, as discussed later in this section, it will be assumed that amitrole is a carcinogen.

### 2.7.2 Atrazine Mutagenesis Tests

A summary and review of mutagenesis tests with atrazine reveal equivocal results. Although a large number of tests were negative, many of the tests with metabolically activated atrazine proved positive in tests indicative of carcinogenic potential. As discussed further below in this section, interim whole animal test results provided to EPA indicate that atrazine is a possible animal carcinogen.

In tests indicative of heritable mutagenic potential, atrazine tested negative (nonmutagenic) both with and without metabolic activation. Likewise a three-generation rat reproduction study showed no effects at the highest doses tested (100 ppm in food) (U. S. EPA 1981).

### 2.7.3 2,4-D Mutagenesis Tests

As reviewed in Agriculture Handbook 633 (USDA 1984), 2,4-D is generally nonmutagenic in most of the microbial systems investigated. Equivocal results were obtained in tests with human lymphocytes with both positive and negative results being reported. Assays for detecting unscheduled DNA synthesis with human embryonic lung cells both in the presence and absence of metabolic activation systems were negative. However, as is discussed below, 2,4-D will be assumed to be a carcinogen based on ambiguous evidence from whole animal tests.

Tests of potential for initiation of heritable mutations including tests with Drosophila and tests for mouse dominant lethal mutations are all reported to give nonmutagenic results (USDA 1984). A three-generation rat feeding showed no reproductive impairment at doses up to 1,500 ppm in food (USEPA 1982b).

### 2.7.4 Dicamba Mutagenesis Tests

Dicamba has not shown mutagenic potential in mutagenesis tests ranging from S. typhimurium to human fibroblasts. A 3-year rat reproduction study also showed no effects at dicamba levels as high as 500 ppm in food (USEPA 1983a). Based on these results, dicamba is not considered mutagenic.

### 2.7.5 Glyphosate Mutagenesis Tests

As reported in Agriculture Handbook 633 (USDA 1984), microbial mutagenesis tests with eight strains of bacteria and yeasts all showed no mutagenic effect for glyphosate. No evidence of mutagenicity was observed in the dominant lethal mutation assays with mice.

### 2.7.6 Hexazinone Mutagenesis Tests

As reported in Agricultural Handbook 633 (USDA 1984), hexazinone gave negative results for mutagenesis in a variety of tests designed to show carcinogenic potential. In test systems with Chinese hamster ovary (CHO) cells, mutagenic results were reported in a subset of *in vitro* cytogenic assays.

Hexazinone showed no effects in three-generation rat reproduction studies at doses up to 2,500 ppm in food (USEPA 1983b).

### 2.7.7 Picloram Mutagenesis Tests

Picloram has shown no mutagenic potential in a standard battery of microbial mutagenesis assays. Only in unvalidated assay systems did picloram show mutagenic activity (USDA 1984).

In a study to determine possible cytogenic effects on bone marrow cells in animals, picloram was fed to rats at dosages up to 2,000 mg/kg without adverse effects.

As is discussed below, ambiguous evidence from whole animal carcinogenesis studies form the basis for assuming that picloram is a carcinogen in this risk analysis.

### 2.7.8 Carcinogenic Potential of Herbicides

In keeping with the worst-case basis of this risk analysis, a herbicide is considered to have carcinogenic potential if whole animal test data indicates oncogenic activity no matter how weak.

EPA is currently reviewing toxicity test data for 2,4-D and has requested additional testing of this compound. An on-going chronic (2-year) rat-feeding study will be completed in 1986. In the interim, there have been at least two studies of the carcinogenic potential of 2,4-D.

As part of a study involving a large number of chemicals, Innes et al. (1969) exposed mice of two strains orally to two different formulations of 2,4-D for 18 months. Eighteen mice of each sex and each strain were exposed to each formulation. Exposure to 2,4-D did not result in any significant increases in tumors in this experiment.

Hansen et al. (1971) exposed Osborne-Mendel rats to 0, 5, 25, 125, 625, or 1,250 ppm 2,4-D in the diet for 2 years. There were 25 male and 25 female rats in each dosage group. No significant effect of dosage on survival was noted. Total numbers of rats with tumors in the control group was 15, and the tumors in the treated groups, by increasing dose, were 14, 18, 20, 23, and 22. Because the tumors were typical of those normally found in aging Osborne-Mendel rats and no target organ tumors were involved, the authors did not attribute these lesions to the feeding of 2,4-D. If one were to assume a relationship between dose and tumor incidence, it is possible to calculate statistical upper limits on the carcinogenic potency of 2,4-D from the studies described above. These upper limits on the carcinogenic potency of 2,4-D will be calculated using a one-hit model of cancer. This model is the most conservative (i.e.,

predicts the highest risks) of any of the cancer models which have gained some acceptance. The one-hit model assumes no threshold or, in other words, that even a single molecule of 2,4-D might cause cancer. This model was used for a time by the EPA to estimate cancer risks before being replaced by a less conservative multistage model of cancer.

The one-hit model was fit separately to the male and female rat data on total animals with tumors from Hansen et al. (1971) using the computer program GLOBAL82 (Howe and Crump 1982). The data on females gave the largest 95 percent statistical upper limit on the carcinogenic potency of 2,4-D (i.e., largest 95 percent upper limit on the linear term in the one-hit model of cancer). This upper limit was $3.01 \times 10^{-4}$ per ppm or $5.03 \times 10^{-3}$ per (mg/kg/day). The utility of this factor is explained below.

The data on the carcinogenic potential of picloram are also ambiguous. The National Cancer Institute (1978) conducted a bioassay of picloram and interpreted the findings as "suggestive of ability of the compound to induce benign tumors in livers of female Osborne-Mendel rats." The benign lesion that suggested this effect was foci of cellular alteration in liver. The one-hit model can be applied to data on this lesion in the manner described for 2,4-D. The 95 percent upper limit calculated in this fashion for the carcinogenic potency of picloram is $3.4 \times 10^{-5}$ per ppm or $5.68 \times 10^{-4}$ per (mg/kg/day). This value is approximately one-tenth of the 2,4-D value.

The data on the carcinogenic potential of amitrole is much less ambiguous and indicates carginogenic effects in mammals exposed to amitrole. EPA has classified amitrole as a "probable human carcinogen." Amitrole cancer potency was estimated using data from three studies:

1. A 2-year rat-feeding study conducted by Hazleton Laboratories, Inc.

2. A study by Tsuda et al. (1976) in which rats were given 2,500 ppm in their drinking water.

3. A study by Food and Drug Research (1981, as cited in EPA, 1985c) in which rats alternately were fed food with and without amitrole.

The cancer potency for amitrole estimated from the Hazleton Labs rat study data was 0.15 per (mg/kg/day). The data of Tsuda et al. (1976) gave a potency of 0.011 per (mg/kg/day) for all invasive thyroid lesions and $9.8 \times 10^{-4}$ per (mg/kg/day) for papillary adenoma. The Food and Drug Research 1981 study (as cited in EPA 1985c) indicated a cancer potency for thyroid tumors of 0.61 (considering only the intermittently dosed groups). In this risk assessment, the greatest of these factors is used to estimate human cancer risk. The 95 percent upper confidence limit for the potency based on the Food and Drug Research data is 1.4 per (mg/kg/day).

EPA is currently reviewing glyphosate carcinogenicity studies submitted by Monsanto (IBT replacement studies). Feeding studies (2-year) with both rats and mice have been conduted. Well conducted rat studies showed no oncogenic activity in either sex. A mouse study is currently being reviewed by EPA. In brief, this 2-year mouse oncogenicity (cancer) study was conducted with glyphosate feed levels of 1,000 parts per million (ppm) in food; 5,000 ppm in food; 30,000 ppm in food; and a control group. Each feed level was comprised of 50 animals of each sex.

The number of male mice with tumors (renal tubular adenomas) was 0 at the 1,000 ppm group, one in the 5,000 ppm group, and three in the 30,000 ppm group. No females had tumors at any dose level. There is some controversy over whether there was one or 0 tumors in the male control (untreated) animals. EPA has ordered Monsanto to recut and re-examine tissues from these animals to resolve the controversy. As noted in the 2,4-D studies, tumors in the control (untreated) mice are not unusual although tumors of the type found in this study have rarely been found in untreated (control) mice.

In reviewing the oncogenicity studies of glyphosate several conclusions can be drawn. First, these feeding studies reaffirm the relatively low toxicity of glyphosate. The highest dose levels of 30,000 ppm means that 3 percent of the mouse daily food intake was glyphosate.

Second, the weight of evidence as indicated by both mouse- and rat-feeding studies indicates at most weak oncogenic effect from glyphosate dose.

In summarizing the information on glyphosate oncogencity, EPA (1985b) has concluded:

> Thus, in well-conducted oncogenicity studies on both sexes of two species, the incidence of only one tumor type in one sex of one species was found to have an increase related to treatment with glyphosate. This increase in tumors occurred only at very high exposure levels (much higher than usual in long-term studies of pesticides). Furthermore, the positive finding depends upon the presence of tumors in only four treated animals.
>
> The factors listed in the paragraph above indicate that the evidence for oncogencity, though present, is extremely limited. According to the Agency's proposed carcinogen risk assessment guidelines (49 FR 46294), glyphosate would be classified in Category C which is used for agents with limited evidence of carcinogenicity in animals in the absence of human data. Category C is the lowest weight-of-evidence category among the categories with any positive evidence.
>
> In addition to the limited amount of quantitative evidence supporting a conclusion of oncogenicity, a quantitative risk estimate indicates that, to the extent that glyphosate is actually an oncogen, it is likely to have only a weak oncogenicity effect. This is primarily related to the extremely high doses at which effects were observed in the study as compared to likely human exposure. Therefore, based on the information currently available, the Agency does not expect any significant risk from the level of glyphosate to which humans are likely to be exposed.

This risk analysis assumes that glyphosate is a carcinogen. The 95 percent limit of the cancer potency calculated from the kidney tumor data is $3.4 \times 10^{-5}$ per (mg/kg/day).

Chronic tests of the herbicides hexazinone, and dicamba, as reviewed in USDA 1984, indicate no carcinogenic potential for these compounds. Interim test results from a 2-year feeding study with atrazine indicate possible

carcinogenic activity with this compound (Spencer 1985). Data is not available from which to calculate cancer potency factors. These factors would be necessary in the event that use of atrazine is proposed in this region.

The probability of the occurrence of cancer over a lifetime as a result of exposure to 2,4-D, picloram, amitrole, or glyphosate can be determined using the following equation:

$$Pc = q^* \times D \times De/L$$

where

Pc = worst-case estimate of the probability of cancer as a result of the dose

$q^*$ = the upper limit of the carcinogenic potency slope ($5.03 \times 10^{-3}$ per (mg/kg/day) for 2,4-D; $5.68 \times 10^{-4}$ per (mg/kg/day) for picloram; 1.4 per (mg/kg/day) for amitrole; and $3.4 \times 10^{-5}$ per (mg/kg/day) for glyphosate.

D = daily dose in mg/kg/day

De = number of days during which the daily dose occurs

L = days in a lifetime (25,550).

Using this equation, the incremental probability of cancer in a lifetime from each exposure pathway can be calculated for model projects applying 2,4-D, picloram, glyphosate, or amitrole. These probabilities are provided on Tables 2.75 through 2.97 for workers and for members of the general population. For example, the probability of a worker with a backpack sprayer developing cancer after spraying 2,4-D for 1 day (with a major mixing error) on small, open-range projects is $8.3 \times 10^{-8}$ ($5.03 \times 10^{-3}$ per (mg/kg/day) x 0.42 mg/kg/day x 1 day x lifetime/25,550 days). A cancer probability of $8.3 \times 10^{-8}$ means that the worker has about eight chances in one hundred million of developing cancer as a result of this dose. The worker's probability of cancer as a result of 30 days spraying assuming he gets a worst-case dose each day is $2.5 \times 10^{-6}$ ($30 \times 8.3 \times 10^{-8}$) or about 2-1/2 chances in one million. If over the 30 days the worker gets an average dose as measured by Lavy et al. (1984), his cancer probability would be about one-fourth the worst-case probability or about six chances in 10 million.

Calculation of the cancer probabilities for various members of the general population requires an estimate of the daily dose and the number of days over which the dose will occur. The maximum-exposed resident in the vicinity of a small, open-range project is assumed to receive a drift dose for 1 day, to consume drift-contaminated vegetables for 42 days and herbicide-contaminated beef for 140 days. The herbicide concentration on vegetation is assumed to remain constant for 2 weeks, to fall to one-half initial values for the next 2 weeks, and by another one-half for the next 2 weeks. This step function decrease in concentration will overestimate concentrations for relatively persistent pesticides such as picloram. The combination of physical and biological degradation, removal by rain and/or irrigation, and new growth will reduce concentrations at a faster rate than assumed here.

Similar assumptions were made for residents and visitors in the vicinity of mid-sized and large, open-range projects except that 2 days' drift dose was assumed for residents near mid-sized projects and 3 days' drift dose near large projects. In addition to the routes of exposure for residents near open-range projects, residents near right-of-way projects were assumed to get a one-time dose from eating contaminated fish and drinking contaminated water.

The cancer probabilities for the general population on Tables 2.76 through 2.97 (exclusive of worker tables) are provided for each exposure pathway and include consideration of dose duration (in days). For example, the cancer probabilities provided on Table 2.91 for an adult resident and a visitor are calculated as follows for large open-range projects sprayed with 2,4-D:

Drift: probability = $1.3 \times 10^{-10} = 5.03 \times 10^{-3}$ per (mg/kg/day) x $2.2 \times 10^{-4}$ mg/kg/day x 3 days x lifetime/25,550 days.

Oral dose beef: probability = $2.0 \times 10^{-8} = 5.03 \times 10^{-3}$ per (mg/kg/day) x $7.1 \times 10^{-4}$ mg/kg/day x 140 days x lifetime/25,550 days

Oral dose vegetable: probability = $4.6 \times 10^{-8} = 5.03 \times 10^{-3}$ per (mg/kg/day) x ($9.6 \times 10^{-3}$ mg/kg/day x 14 days + $4.8 \times 10^{-3}$ x 14 days + $2.4 \times 10^{-3}$ x 14 days) x lifetime/25,550 days

Visitor re-entry: probability = $1.6 \times 10^{-9} = 5.03 \times 10^{-3}$ per (mg/kg/day) x $8.0 \times 10^{-3}$ mg/kg/day x 1 day x lifetime/25,550 days

Oral dose wild food: probability = $1.1 \times 10^{-8} = 5.03 \times 10^{-3}$ per (mg/kg/day) x $5.6 \times 10^{-2}$ mg/kg/day x 1 day x lifetime/25,550 days.

The cumulative impact on the maximum-exposed resident from doses from each of the exposure pathways is the sum of the probabilities from the individual pathways. For the maximum-exposed adult resident near a large, open-range project sprayed with 2,4-D (see Table 2.91), the cumulative cancer probability from all three exposure pathways is $6.613 \times 10^{-8}$ ($1.3 \times 10^{-10}$ + $2.0 \times 10^{-8}$ + $4.6 \times 10^{-8}$) or about six chances in one hundred million. If this resident were exposed to five projects in a lifetime and each time received the maximum dose (in itself a very, very low probability event), his probability of cancer would be $3.3 \times 10^{-7}$ or about three chances in ten million.

Considering only herbicides used in Region 1, (thus excluding amitrole) the highest cancer probability occurs with an infant resident near a large, open-range project sprayed with 2,4-D. The infant's cumulative cancer probability is $8.1 \times 10^{-8}$ or about eight chances in one hundred million.

As a point of comparison and to further illustrate the reality of such small probabilities, Table 2.98 provides a list of events which result in a one-in-a-million chance of death. As shown on Table 2.98, the average American has about a one-in-a-million chance of being killed in fire for every 13 days of living in the U.S. His probability of fire fatality for 1 year would be about $2.8 \times 10^{-5}$ ($1 \times 10^{-6}$/13 days x 365 days/year), or about three chances in 100,000. A worker in the transport and public utilities section of industry (e.g., a truck driver) has a one-in-a-million chance of death every day on the job. A person who smokes two cigarettes has increased his probability of cancer by one chance in a million.

Table 2.75--Cancer probabilities for workers spraying small, open-range projects for 1 day.

| | Lifetime cancer probability from 1 day's spraying assuming minor mixing error | Lifetime cancer probability from 1 day's spraying assuming major mixing errors |
|---|---|---|
| 2,4-D | $7.3 \times 10^{-8}$ | $8.3 \times 10^{-8}$ |
| Picloram | $4.0 \times 10^{-9}$ | $4.7 \times 10^{-9}$ |
| Glyphosate | $2.4 \times 10^{-10}$ | $2.8 \times 10^{-10}$ |
| 2,4-D/ Picloram | $3.5 \times 10^{-8}$/ $1.1 \times 10^{-9}$ | $4.1 \times 10^{-8}$/ $1.3 \times 10^{-9}$ |
| 2,4-D/ Dicamba | $4.3 \times 10^{-8}$ | $5.1 \times 10^{-8}$ |
| Amitrole | $9.9 \times 10^{-6}$ | $1.2 \times 10^{-5}$ |

Table 2.76--Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with 2,4-D.

| | Lifetime cancer probability assuming minor mixing errors | Lifetime cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $9.8 \times 10^{-12}$ | $1.3 \times 10^{-11}$ |
| Adolescent dermal dose | $1.3 \times 10^{-11}$ | $1.5 \times 10^{-11}$ |
| Infant dermal dose | $2.4 \times 10^{-11}$ | $3.0 \times 10^{-11}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $2.0 \times 10^{-8}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $2.3 \times 10^{-8}$ |
| Adult/adolescent oral dose (veg) | $8.8 \times 10^{-9}$ | $1.1 \times 10^{-8}$ |
| Infant oral dose (veg) | $1.1 \times 10^{-8}$ | $1.3 \times 10^{-8}$ |
| Visitor re-entry to spray site 1 day | $1.5 \times 10^{-11}$ | $1.9 \times 10^{-11}$ |
| Oral dose/sprayed wild food 1 day | $1.1 \times 10^{-8}$ | $1.3 \times 10^{-8}$ |

Table 2.77--Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with picloram.

| | Lifetime cancer probability assuming minor mixing errors | Lifetime cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $5.6 \times 10^{-14}$ | $7.1 \times 10^{-14}$ |
| Adolescent dermal dose | $7.1 \times 10^{-14}$ | $8.9 \times 10^{-14}$ |
| Infant dermal dose | $1.3 \times 10^{-13}$ | $1.6 \times 10^{-13}$ |
| Adult/adolescent oral dose (beef) | $2.2 \times 10^{-9}$ | $2.2 \times 10^{-9}$ |
| Infant oral dose (beef) | $2.6 \times 10^{-9}$ | $2.6 \times 10^{-9}$ |
| Adult/adolescent oral dose (veg) | $4.9 \times 10^{-10}$ | $6.0 \times 10^{-10}$ |
| Infant oral dose (veg) | $5.6 \times 10^{-10}$ | $7.0 \times 10^{-10}$ |
| Visitor re-entry to spray site 1 day | $8.7 \times 10^{-13}$ | $1.1 \times 10^{-12}$ |
| Oral dose/sprayed wild food 1 day | $6.2 \times 10^{-10}$ | $7.5 \times 10^{-10}$ |

Table 2.78--Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with glyphosate.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $3.3 \times 10^{-14}$ | $4.3 \times 10^{-14}$ |
| Adolescent dermal dose | $4.3 \times 10^{-14}$ | $5.2 \times 10^{-14}$ |
| Infant dermal dose | $7.8 \times 10^{-14}$ | $1.0 \times 10^{-13}$ |
| Adult/adolescent oral dose (beef) | $1.3 \times 10^{-10}$ | $1.3 \times 10^{-10}$ |
| Infant oral dose (beef) | $1.5 \times 10^{-10}$ | $1.5 \times 10^{-10}$ |
| Adult/adolescent oral dose (veg) | $2.9 \times 10^{-11}$ | $3.6 \times 10^{-11}$ |
| Infant oral dose (veg) | $3.6 \times 10^{-11}$ | $4.6 \times 10^{-11}$ |
| Visitor re-entry to spray site 1 day | $5.2 \times 10^{-14}$ | $6.3 \times 10^{-14}$ |
| Oral dose/sprayed wild food 1 day | $3.7 \times 10^{-11}$ | $4.5 \times 10^{-11}$ |

Table 2.79--Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/picloram mixture.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $4.9 \times 10^{-12}/1.4 \times 10^{-14}$ | $6.5 \times 10^{-12}/1.8 \times 10^{-14}$ |
| Adolescent dermal dose | $6.3 \times 10^{-12}/1.8 \times 10^{-14}$ | $7.6 \times 10^{-12}/2.2 \times 10^{-14}$ |
| Infant dermal dose | $1.2 \times 10^{-11}/3.3 \times 10^{-14}$ | $1.4 \times 10^{-11}/4.2 \times 10^{-14}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}/2.2 \times 10^{-9}$ | $2.0 \times 10^{-8}/2.2 \times 10^{-9}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}/2.6 \times 10^{-9}$ | $2.3 \times 10^{-8}/2.6 \times 10^{-9}$ |
| Adult/adolescent oral dose (veg) | $4.3 \times 10^{-9}/1.2 \times 10^{-10}$ | $5.6 \times 10^{-9}/1.5 \times 10^{-10}$ |
| Infant oral dose (veg) | $5.1 \times 10^{-9}/1.5 \times 10^{-10}$ | $7.3 \times 10^{-9}/1.9 \times 10^{-1}$ |
| Visitor re-entry to spray site 1 day | $7.7 \times 10^{-12}/2.2 \times 10^{-13}$ | $9.4 \times 10^{-12}/2.7 \times 10^{-13}$ |
| Oral dose/sprayed wild food 1 day | $5.5 \times 10^{-9}/1.6 \times 10^{-10}$ | $6.7 \times 10^{-9}/1.9 \times 10^{-10}$ |

Table 2.80--Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with a 2,4-D/dicamba mixture.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $5.9 \times 10^{-12}$ | $7.5 \times 10^{-12}$ |
| Adolescent dermal dose | $7.6 \times 10^{-12}$ | $9.4 \times 10^{-12}$ |
| Infant dermal dose | $1.4 \times 10^{-11}$ | $1.8 \times 10^{-11}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $2.0 \times 10^{-8}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $2.3 \times 10^{-8}$ |
| Adult/adolescent oral dose (veg) | $5.3 \times 10^{-9}$ | $6.2 \times 10^{-9}$ |
| Infant oral dose (veg) | $6.8 \times 10^{-9}$ | $8.7 \times 10^{-9}$ |
| Visitor re-entry to spray site 1 day | $9.4 \times 10^{-12}$ | $1.1 \times 10^{-11}$ |
| Oral dose/sprayed wild food 1 day | $6.7 \times 10^{-9}$ | $8.2 \times 10^{-9}$ |

Table 2.81--Cancer probabilities for visitors and residents in the vicinity of a small, open-range project sprayed with amitrole.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $1.4 \times 10^{-10}$ | $1.8 \times 10^{-10}$ |
| Adolescent dermal dose | $1.8 \times 10^{-10}$ | $2.1 \times 10^{-10}$ |
| Infant dermal dose | $3.2 \times 10^{-10}$ | $4.0 \times 10^{-10}$ |
| Adult/adolescent oral dose (beef) | $5.4 \times 10^{-6}$ | $5.4 \times 10^{-6}$ |
| Infant oral dose (beef) | $6.3 \times 10^{-6}$ | $6.3 \times 10^{-6}$ |
| Adult/adolescent oral dose (veg) | $1.2 \times 10^{-6}$ | $1.5 \times 10^{-6}$ |
| Infant oral dose (veg) | $1.5 \times 10^{-6}$ | $1.9 \times 10^{-6}$ |
| Visitor re-entry to spray site 1 day | $2.1 \times 10^{-9}$ | $2.6 \times 10^{-9}$ |
| Oral dose/sprayed wild food 1 day | $1.5 \times 10^{-6}$ | $1.9 \times 10^{-6}$ |

Table 2.82--Daily cancer probabilities for workers from spraying mid-sized, open-range projects.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| 2,4-D | $1.6 \times 10^{-7}$ | $1.7 \times 10^{-7}$ |
| Picloram | $8.9 \times 10^{-9}$ | $9.3 \times 10^{-9}$ |
| Glyphosate | $5.3 \times 10^{-10}$ | $5.7 \times 10^{-10}$ |
| 2,4-D/Picloram | $7.9 \times 10^{-8}$/ $2.2 \times 10^{-9}$ | $8.5 \times 10^{-8}$/ $2.4 \times 10^{-9}$ |
| 2,4-D/Dicamba | $9.7 \times 10^{-8}$ | $1.0 \times 10^{-7}$ |
| Amitrole | $2.2 \times 10^{-5}$ | $2.4 \times 10^{-5}$ |

Table 2.83--Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with 2,4-D.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $3.2 \times 10^{-11}$ | $4.0 \times 10^{-11}$ |
| Adolescent dermal dose | $4.3 \times 10^{-11}$ | $5.1 \times 10^{-11}$ |
| Infant dermal dose | $8.0 \times 10^{-11}$ | $1.0 \times 10^{-10}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $2.0 \times 10^{-8}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $2.3 \times 10^{-8}$ |
| Adult/adolescent oral dose (veg) | $1.5 \times 10^{-8}$ | $1.9 \times 10^{-8}$ |
| Infant oral dose (veg) | $1.8 \times 10^{-8}$ | $2.3 \times 10^{-8}$ |
| Visitor re-entry to spray site 1 day | $1.0 \times 10^{-10}$ | $1.2 \times 10^{-10}$ |
| Oral dose/sprayed wild food 1 day | $1.1 \times 10^{-8}$ | $1.3 \times 10^{-8}$ |

Table 2.84--Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with picloram.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $1.8 \times 10^{-13}$ | $2.4 \times 10^{-13}$ |
| Adolescent dermal dose | $3.2 \times 10^{-13}$ | $4.1 \times 10^{-13}$ |
| Infant dermal dose | $5.7 \times 10^{-13}$ | $7.4 \times 10^{-13}$ |
| Adult/adolescent oral dose (beef) | $2.2 \times 10^{-9}$ | $2.2 \times 10^{-9}$ |
| Infant oral dose (beef) | $2.5 \times 10^{-9}$ | $2.5 \times 10^{-9}$ |
| Adult/adolescent oral dose (veg) | $8.2 \times 10^{-10}$ | $1.1 \times 10^{-9}$ |
| Infant oral dose (veg) | $1.0 \times 10^{-9}$ | $1.1 \times 10^{-9}$ |
| Visitor re-entry to spray site 1 day | $5.8 \times 10^{-12}$ | $7.1 \times 10^{-12}$ |
| Oral dose/sprayed wild food 1 day | $6.2 \times 10^{-10}$ | $7.5 \times 10^{-10}$ |

Table 2.85--Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with glyphosate.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $1.1 \times 10^{-13}$ | $1.4 \times 10^{-13}$ |
| Adolescent dermal dose | $1.4 \times 10^{-13}$ | $1.7 \times 10^{-13}$ |
| Infant dermal dose | $2.6 \times 10^{-13}$ | $3.1 \times 10^{-13}$ |
| Adult/adolescent oral dose (beef) | $1.3 \times 10^{-10}$ | $1.3 \times 10^{-10}$ |
| Infant oral dose (beef) | $1.5 \times 10^{-10}$ | $1.5 \times 10^{-10}$ |
| Adult/adolescent oral dose (veg) | $4.9 \times 10^{-11}$ | $6.2 \times 10^{-11}$ |
| Infant oral dose (veg) | $6.2 \times 10^{-11}$ | $7.8 \times 10^{-11}$ |
| Visitor re-entry to spray site 1 day | $3.5 \times 10^{-13}$ | $4.3 \times 10^{-13}$ |
| Oral dose/sprayed wild food 1 day | $3.7 \times 10^{-11}$ | $4.5 \times 10^{-11}$ |

Table 2.86--Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/picloram mixture.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $1.6 \times 10^{-11}/4.4 \times 10^{-14}$ | $2.1 \times 10^{-11}/5.8 \times 10^{-14}$ |
| Adolescent dermal dose | $2.1 \times 10^{-11}/5.8 \times 10^{-14}$ | $2.5 \times 10^{-11}/7.1 \times 10^{-14}$ |
| Infant dermal dose | $3.9 \times 10^{-11}/1.1 \times 10^{-13}$ | $4.7 \times 10^{-11}/1.3 \times 10^{-13}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ /$2.2 \times 10^{-9}$ | $2.0 \times 10^{-8}/2.2 \times 10^{-9}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ /$2.5 \times 10^{-9}$ | $2.3 \times 10^{-8}/2.5 \times 10^{-9}$ |
| Adult/adolescent oral dose (veg) | $7.2 \times 10^{-9}/2.1 \times 10^{-10}$ | $9.2 \times 10^{-9}/2.7 \times 10^{-10}$ |
| Infant oral dose (veg) | $9.2 \times 10^{-9}/2.7 \times 10^{-10}$ | $1.2 \times 10^{-8}/3.3 \times 10^{-10}$ |
| Visitor re-entry to spray site 1 day | $5.1 \times 10^{-11}/1.4 \times 10^{-12}$ | $6.3 \times 10^{-11}/1.8 \times 10^{-12}$ |
| Oral dose/sprayed wild food 1 day | $5.5 \times 10^{-9}$ /$1.6 \times 10^{-10}$ | $6.7 \times 10^{-9}/1.9 \times 10^{-10}$ |

Table 2.87--Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with a 2,4-D/dicamba mixture.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $2.0 \times 10^{-11}$ | $2.3 \times 10^{-11}$ |
| Adolescent dermal dose | $2.6 \times 10^{-11}$ | $3.2 \times 10^{-11}$ |
| Infant dermal dose | $4.7 \times 10^{-11}$ | $6.3 \times 10^{-11}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $2.0 \times 10^{-8}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $2.3 \times 10^{-8}$ |
| Adult/adolescent oral dose (veg) | $9.2 \times 10^{-9}$ | $1.1 \times 10^{-8}$ |
| Infant oral dose (veg) | $1.2 \times 10^{-8}$ | $1.5 \times 10^{-8}$ |
| Visitor re-entry to spray site 1 day | $6.3 \times 10^{-11}$ | $7.9 \times 10^{-11}$ |
| Oral dose/sprayed wild food 1 day | $6.7 \times 10^{-9}$ | $8.3 \times 10^{-9}$ |

Table 2.88--Cancer probabilities for visitors and residents in the vicinity of a mid-sized, open-range project sprayed with amitrole.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| Adult dermal dose | $4.5 \times 10^{-10}$ | $5.8 \times 10^{-10}$ |
| Adolescent dermal dose | $5.8 \times 10^{-10}$ | $7.1 \times 10^{-10}$ |
| Infant dermal dose | $1.1 \times 10^{-9}$ | $1.3 \times 10^{-9}$ |
| Adult/adolescent oral dose (beef) | $5.4 \times 10^{-6}$ | $5.4 \times 10^{-6}$ |
| Infant oral dose (beef) | $6.4 \times 10^{-6}$ | $6.4 \times 10^{-6}$ |
| Adult/adolescent oral dose (veg) | $2.0 \times 10^{-6}$ | $2.6 \times 10^{-6}$ |
| Infant oral dose (veg) | $2.6 \times 10^{-6}$ | $3.2 \times 10^{-6}$ |
| Visitor re-entry to spray site 1 day | $1.4 \times 10^{-8}$ | $1.8 \times 10^{-8}$ |
| Oral dose/sprayed wild food 1 day | $1.5 \times 10^{-6}$ | $1.9 \times 10^{-6}$ |

Table 2.89--Daily cancer probabilities for backpack sprayers on large, open-range projects.

| | Cancer probability assuming minor mixing errors | Cancer probability assuming major mixing errors |
|---|---|---|
| 2,4-D | $1.6 \times 10^{-7}$ | $1.7 \times 10^{-7}$ |
| Picloram | $8.9 \times 10^{-9}$ | $9.3 \times 10^{-9}$ |
| Glyphosate | $5.3 \times 10^{-10}$ | $5.7 \times 10^{-10}$ |
| 2,4-D/Picloram | $7.9 \times 10^{-8}$/ $2.2 \times 10^{-9}$ | $8.5 \times 10^{-8}$/ $2.4 \times 10^{-9}$ |
| 2,4-D/dicamba | $9.7 \times 10^{-8}$ | $1.0 \times 10^{-7}$ |
| Amitrole | $2.2 \times 10^{-5}$ | $2.4 \times 10^{-5}$ |

Table 2.90--Daily cancer probabilities for truck drivers and supervisors on large, open-range projects.

| | Supervisor | Truck driver |
|---|---|---|
| 2,4-D | $1.6 \times 10^{-9}$ | $1.3 \times 10^{-7}$ |
| Picloram | $8.9 \times 10^{-11}$ | $7.3 \times 10^{-9}$ |
| Glyphosate | $5.3 \times 10^{-12}$ | $4.4 \times 10^{-10}$ |
| 2,4-D/picloram | $7.9 \times 10^{-10}$/ $2.2 \times 10^{-11}$ | $6.5 \times 10^{-8}$/ $1.8 \times 10^{-9}$ |
| 2,4-D/dicamba | $9.7 \times 10^{-10}$ | $7.9 \times 10^{-8}$ |
| Amitrole | $2.2 \times 10^{-7}$ | $1.8 \times 10^{-5}$ |

Table 2.91--Cancer probabilities for visitors and residents in the vicinity of a large, open-range project sprayed with 2,4-D, picloram, or glyphosate.

| | Cancer probability (2,4-D) | Cancer probability (picloram) | Cancer probability (glyphosate) |
|---|---|---|---|
| Adult dermal dose | $1.3 \times 10^{-10}$ | $7.3 \times 10^{-13}$ | $4.3 \times 10^{-13}$ |
| Adolescent dermal dose | $1.8 \times 10^{-10}$ | $1.0 \times 10^{-12}$ | $6.0 \times 10^{-13}$ |
| Infant dermal dose | $3.3 \times 10^{-10}$ | $1.8 \times 10^{-12}$ | $1.1 \times 10^{-12}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $2.2 \times 10^{-9}$ | $1.3 \times 10^{-10}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $2.6 \times 10^{-9}$ | $1.5 \times 10^{-10}$ |
| Adult/adolescent oral dose (veg) | $4.6 \times 10^{-8}$ | $2.6 \times 10^{-9}$ | $1.6 \times 10^{-10}$ |
| Infant oral dose (veg) | $5.8 \times 10^{-8}$ | $3.4 \times 10^{-9}$ | $2.0 \times 10^{-10}$ |
| Visitor re-entry to spray site 1 day | $1.6 \times 10^{-9}$ | $8.9 \times 10^{-11}$ | $5.3 \times 10^{-12}$ |
| Oral dose/sprayed wild food 1 day | $1.1 \times 10^{-8}$ | $6.2 \times 10^{-10}$ | $3.7 \times 10^{-11}$ |

Table 2.92--Cancer probabilities for visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/picloram mixture.

| | Probability from 2,4-D dose | Probability from picloram dose |
|---|---|---|
| Adult dermal dose | $6.5 \times 10^{-11}$ | $2.0 \times 10^{-13}$ |
| Adolescent dermal dose | $8.9 \times 10^{-11}$ | $2.7 \times 10^{-13}$ |
| Infant dermal dose | $1.6 \times 10^{-10}$ | $4.7 \times 10^{-13}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $2.2 \times 10^{-9}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $2.6 \times 10^{-9}$ |
| Adult/adolescent oral dose (veg) | $2.3 \times 10^{-8}$ | $6.5 \times 10^{-10}$ |
| Infant oral dose (veg) | $3.0 \times 10^{-8}$ | $8.7 \times 10^{-10}$ |
| Visitor re-entry to spray site 1 day | $7.9 \times 10^{-11}$ | $2.4 \times 10^{-12}$ |
| Oral dose/sprayed wild food 1 day | $5.5 \times 10^{-9}$ | $1.6 \times 10^{-10}$ |

Table 2.93--Cancer probability for visitors and residents in the vicinity of a large, open-range project sprayed with a 2,4-D/dicamba mixture or amitrole.

| | Probability from 2,4-D/dicamba mixture | Probability from amitrole dose |
|---|---|---|
| Adult dermal dose | $8.2 \times 10^{-11}$ | $1.8 \times 10^{-9}$ |
| Adolescent dermal dose | $1.1 \times 10^{-10}$ | $2.4 \times 10^{-9}$ |
| Infant dermal dose | $2.0 \times 10^{-10}$ | $4.4 \times 10^{-9}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-8}$ | $5.4 \times 10^{-6}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-8}$ | $6.4 \times 10^{-6}$ |
| Adult/adolescent oral dose (veg) | $3.0 \times 10^{-8}$ | $6.4 \times 10^{-6}$ |
| Infant oral dose (veg) | $3.7 \times 10^{-8}$ | $8.3 \times 10^{-6}$ |
| Visitor re-entry to spray site 1 day | $9.7 \times 10^{-11}$ | $2.2 \times 10^{-7}$ |
| Oral dose/sprayed wild food 1 day | $6.7 \times 10^{-9}$ | $1.5 \times 10^{-6}$ |

Table 2.94--Daily cancer probabilities for workers spraying riparian/right-of-way projects.

| | Truck driver | Spot sprayer |
|---|---|---|
| 2,4-D | $3.2 \times 10^{-8}$ | $1.6 \times 10^{-7}$ |
| Picloram | $1.8 \times 10^{-9}$ | $8.9 \times 10^{-9}$ |
| Glyphosate | $1.1 \times 10^{-10}$ | $5.3 \times 10^{-10}$ |
| 2,4-D/picloram | $1.6 \times 10^{-8}/4.4 \times 10^{-10}$ | $7.9 \times 10^{-8}/2.2 \times 10^{-9}$ |
| 2,4-D/dicamba | $2.0 \times 10^{-8}$ | $9.7 \times 10^{-8}$ |
| Amitrole | $4.4 \times 10^{-6}$ | $2.2 \times 10^{-5}$ |

Table 2.95--Cancer probabilities for visitors and residents in the vicinity of riparian/right-of-way projects sprayed with 2,4-D, picloram, or glyphosate.

| | Probability from 2,4-D dose | Probability from picloram dose | Probability from glyphosate dose |
|---|---|---|---|
| Adult dermal dose | $7.9 \times 10^{-12}$ | $4.4 \times 10^{-14}$ | $2.7 \times 10^{-14}$ |
| Adolescent dermal dose | $7.5 \times 10^{-9}$ | $4.2 \times 10^{-11}$ | $2.5 \times 10^{-11}$ |
| Infant dermal dose | $1.9 \times 10^{-11}$ | $1.1 \times 10^{-13}$ | $6.4 \times 10^{-14}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-10}$ | $2.2 \times 10^{-11}$ | $1.3 \times 10^{-12}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-10}$ | $2.6 \times 10^{-11}$ | $1.5 \times 10^{-12}$ |
| Adult/adolescent oral dose (veg) | $4.8 \times 10^{-9}$ | $2.8 \times 10^{-10}$ | $1.7 \times 10^{-11}$ |
| Infant oral dose (veg) | $6.3 \times 10^{-9}$ | $3.5 \times 10^{-10}$ | $2.1 \times 10^{-11}$ |
| Visitor re-entry or walk along ROW | $3.5 \times 10^{-10}$ | $2.0 \times 10^{-11}$ | $1.2 \times 10^{-12}$ |
| Adult oral dose (water) | $1.1 \times 10^{-9}$ | $6.4 \times 10^{-11}$ | $3.9 \times 10^{-12}$ |
| Adolescent oral dose (water) | $1.5 \times 10^{-9}$ | $8.4 \times 10^{-11}$ | $5.1 \times 10^{-12}$ |
| Infant oral dose (water) | $1.6 \times 10^{-9}$ | $9.3 \times 10^{-11}$ | $5.6 \times 10^{-12}$ |
| Adult/adolescent oral dose (fish) | $2.0 \times 10^{-11}$ | $1.1 \times 10^{-12}$ | $6.4 \times 10^{-14}$ |
| Infant oral dose (fish) | $2.2 \times 10^{-11}$ | $1.2 \times 10^{-12}$ | $7.4 \times 10^{-14}$ |

Table 2.96--Cancer probabilities for residents in the vicinity of riparian/ right-of-way projects sprayed with a 2,4-D/picloram mixture.

| | Probability from 2,4-D dose | Probability from picloram dose |
|---|---|---|
| Adult dermal dose | $3.9 \times 10^{-12}$ | $1.1 \times 10^{-14}$ |
| Adolescent dermal dose | $3.7 \times 10^{-9}$ | $1.1 \times 10^{-11}$ |
| Infant dermal dose | $9.4 \times 10^{-12}$ | $2.7 \times 10^{-14}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-10}$ | $2.2 \times 10^{-11}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-10}$ | $2.6 \times 10^{-11}$ |
| Adult/adolescent oral dose (veg) | $2.5 \times 10^{-9}$ | $7.1 \times 10^{-11}$ |
| Infant oral dose (veg) | $3.2 \times 10^{-9}$ | $8.2 \times 10^{-11}$ |
| Visitor re-entry or walk along ROW | $1.7 \times 10^{-10}$ | $5.1 \times 10^{-12}$ |
| Adult oral dose (water) | $5.7 \times 10^{-10}$ | $1.6 \times 10^{-11}$ |
| Adolesent oral dose (water) | $7.5 \times 10^{-10}$ | $2.2 \times 10^{-11}$ |
| Infant oral dose (water) | $8.3 \times 10^{-10}$ | $2.4 \times 10^{-11}$ |
| Adult/adolescent oral dose (fish) | $9.5 \times 10^{-12}$ | $3.8 \times 10^{-13}$ |
| Infant oral dose (fish) | $1.1 \times 10^{-11}$ | $4.2 \times 10^{-13}$ |

Table 2.97--Cancer probabilities for visitors and residents in the vicinity of riparian/right-of-way projects sprayed with a 2,4-D/dicamba mixture or amitrole.

| | Probability from 2,4-D/dicamba mixture | Probability from amitrole dose |
|---|---|---|
| Adult dermal dose | $4.9 \times 10^{-12}$ | $1.1 \times 10^{-10}$ |
| Adolescent dermal dose | $4.7 \times 10^{-9}$ | $1.0 \times 10^{-7}$ |
| Infant dermal dose | $1.2 \times 10^{-11}$ | $2.6 \times 10^{-10}$ |
| Adult/adolescent oral dose (beef) | $2.0 \times 10^{-10}$ | $5.4 \times 10^{-8}$ |
| Infant oral dose (beef) | $2.3 \times 10^{-10}$ | $6.4 \times 10^{-8}$ |
| Adult/adolescent oral dose (veg) | $3.0 \times 10^{-9}$ | $6.8 \times 10^{-7}$ |
| Infant oral dose (veg) | $3.9 \times 10^{-9}$ | $8.7 \times 10^{-7}$ |
| Visitor re-entry or walk along ROW | $2.2 \times 10^{-10}$ | $4.8 \times 10^{-8}$ |
| Adult oral dose (water) | $7.1 \times 10^{-10}$ | $1.6 \times 10^{-7}$ |
| Adolescent oral dose (water) | $9.3 \times 10^{-10}$ | $2.1 \times 10^{-7}$ |
| Infant oral dose (water) | $1.0 \times 10^{-9}$ | $2.3 \times 10^{-7}$ |
| Adult/adolescent oral dose (fish) | $1.2 \times 10^{-11}$ | $2.6 \times 10^{-9}$ |
| Infant oral dose (fish) | $1.4 \times 10^{-11}$ | $3.1 \times 10^{-9}$ |

Table 2.98--Lifetime risk of death or cancer resulting from everyday activities (from Crouch and Wilson (1982)).

| Activity | Time to accumulate a one-in-a-million risk of death | Average annual risk per capita |
|---|---|---|
| **Living in the United States** | | |
| Motor vehicle accident | 1.5 days | $2 \times 10^{-4}$ |
| Falls | 6 days | $6 \times 10^{-5}$ |
| Drowning | 10 days | $4 \times 10^{-5}$ |
| Fires | 13 days | $3 \times 10^{-5}$ |
| Firearms | 36 days | $1 \times 10^{-5}$ |
| Electrocution | 2 months | $5 \times 10^{-6}$ |
| Tornados | 20 months | $6 \times 10^{-7}$ |
| Floods | 20 months | $6 \times 10^{-7}$ |
| Lightning | 2 years | $5 \times 10^{-7}$ |
| Animal bite or sting | 4 years | $2 \times 10^{-7}$ |
| **Occupational Risks** | | |
| General | | |
| manufacturing | 4.5 days | $8 \times 10^{-5}$ |
| trade | 7 days | $5 \times 10^{-3}$ |
| service & government | 3.5 days | $1 \times 10^{-4}$ |
| transport & public utilities | 1 day | $4 \times 10^{-4}$ |
| agriculture | 15 hours | $6 \times 10^{-4}$ |
| construction | 14 hours | $6 \times 10^{-4}$ |
| mining and quarrying | 9 hours | $1 \times 10^{-3}$ |
| Specific | | |
| coal mining (accidents) | 14 hours | $6 \times 10^{-4}$ |
| police duty | 1.5 days | $2 \times 10^{-4}$ |
| railroad employment | 1.5 days | $2 \times 10^{-4}$ |
| fire fighting | 11 hours | $8 \times 10^{-4}$ |

**One-In-A-Million Risks of Cancer**

| Source of risk | Type and amount of exposure: examples |
|---|---|
| Cosmic rays | One transcontinental round trip by air; living 1.5 months in Colorado compared to New York; camping at 15,000 feet over 6 days compared to sea level. |
| Other | 20 days of sea level natural background radiation; 2.5 months in masonry rather than wood building; 1/7 of a chest x-ray using moderan equipment. |
| Eating & drinking | 40 diet sodas (saccharin)<br>6 pounds of peanut butter (aflatoxin)<br>180 pints of milk (aflatoxin)<br>200 gallons of drinking water from Miami or New Orleans<br>90 pounds of broiled steak (cancer risk only) |
| Smoking | 2 cigarettes |

!.8 SYNERGISM/CUMULATIVE EFFECTS

This section examines the interaction of these herbicides with other chemicals in the environment and the cumulative effect of these programs on the herbicide already in the environment from other sources. Synergism, which concerns many people, is a special type of interaction where the combined effect of a specific herbicide with one or more chemicals in the environment (such as pollutants) would be greater than the sum of the individual effects of the herbicide and chemical(s) (in other words 2 + 2 is greater than 4).

Chemical interactions may also result in antagonistic effects in which two or more chemicals cause opposite effects on the same physiologic function or decrease the intrinsic activity of one of the components. Most cases of chemical interactions lead to a a decrease in toxicologic activity, and this is one of the common principles of antidotal treatment (U.S. EPA 1984c). Examples include the use of chelating agents to complex with metal ions and the use of ammonia as an antidote to the ingestion of formaldehyde. By comparison, chemical reactions which lead to greater than additive effects appear to be less common and are less well documented.

Since we live in a sea of chemicals, the possibility of chemical/herbicide interaction is certainly probable. However, because of the complex number of possible interactions, the result is not readily predictable.

One way to measure interactive effects is to conduct epidemiological studies on exposed and control populations. However, the interactive effects described are measurably small and the sensitivity of epidemiology tests might not be sufficient to detect such effects particularly at the dose levels occurring with most spray programs and with the small number of people involved.

A classic study of the synergistic effects of pollutants examined the interactive effects of asbestos exposure and smoking. Selikoff et al. (1968) found that inhalation of cigarette smoke and asbestos resulted in an eightfold increase in lung cancer over nonsmokers exposed to only asbestos. Studies such as these, however, have limitations because high doses are required to discover effects and the relevance to low level exposures is uncertain.

Tests for synergistic effects can sometimes be accomplished using short term animal or cellular tests at relatively high dosage levels. For example, Stathan and Lech (1975a and b) have reported the synergistic effects of the pesticide carbaryl on the acute toxicity of 2,4-D in trout, as well as the pesticides dieldrin, rotenone and pentachlorophenol. The acute toxicity of these chemicals was increased by factors of threefold to about eightfold for additions of 1 mg/liter of carbaryl. This amount of carbaryl is much higher than would be present in water under any circumstance except worst-case accident scenarios.

In tests run by Dow Chemical Company on humans at unspecified doses (USDA 1984), no dermal irritation or sensitization was found for mixtures of 6 percent Tordon® (picloram) and 22 percent 2,4-D, 10.2 percent picloram and 39.6 percent 2,4-D salts, or 10 percent picloram only.

In summary then, what can be said concerning the issue of synergistic and cumulative effects relative to the Forest Service noxious weed spray programs?

First, the additive impact of Forest Service spraying on top of general effects of the private application of herbicides will be very small. For example, a worker or farmer who sprays herbicides on non-Forest Service projects and is also a resident in the vicinity of Forest Service projects might expect, under worst-case conditions, an increase in herbicide dose of less than 1 percent over his worker dose (see discussion in Section 2.6). Typically, the increase would not be measurable.

The dose to maximum-exposed residents assumed that the greatest portion of their diet came from spray-impacted foodstuffs. Thus any substitution of food from other sources (i.e., food markets) would lessen the dose. The herbicides most commonly used in Region 1 have not been found widely in market foodstuffs. For example, a market-basket analysis by the Natural Resources Defense Council (NRDC) of a variety of fruits and vegetables found no 2,4-D in any food sample (NRDC 1984).

Although the NRDC found other pesticides in some foodstuffs, the interactive effects would be suspected to be small for maximum-exposed residents. Since the dose or concentration of any chemical dictates both the probability and rate of any chemical reaction (and all biological responses in an organism are the result of chemical reactions), the dose of a specific herbicide in the environment or in the individual is an important factor in considering synergistic effects. Ames (1983) pointed out that there are many naturally occurring chemicals in the food people eat which are teratogenic, mutagenic, and carcinogenic and which are consumed at doses 10,000 times higher than man-made pesticides. Therefore, the low, short-lived doses to maximum-expose residents that result from the spraying of these herbicides to control noxiou weeds are very small compared to many other chemicals in the environment. Fo these small comparative doses, a synergistic effect is not realistically expected (Crouch et al. 1983). EPA apparently came to the same conclusion, because they issued a Notice (PR Notice 82-1) on January 12, 1982 (U.S. EPA 1982a), rescinding the requirement for submission of tank mix compatability data. The Notice stated that EPA had examined considerable data and found no evidence of potentiation involving pesticides.

As discussed throughout this analysis, the highest doses are expected of some types of workers, particularly those involved in the hand application of herbicides. If one assumed synergistic reactions on the order of those observed in the case of asbestos exposure and smoking, then eight to tenfold increases in toxicity might be expected. The most significant impacts might involve workers spraying 2,4-D/dicamba mixtures, one of the more common mixtures used in Region 1. Again, the major concern would be the potential fetotoxic effects on pregnant female applicators. Depending on site-specific plans and needs, this issue may require additional consideration in the site-specific analysis and could require management constraints as discussed in Section 2.6.2.

# 3. ACCIDENT SCENARIOS

## 3.1 Background

Several types of major accidents, their probability of occurrence, and the resultant potential for exposure of human populations are discussed in this section.

Accidents such as large spills at the mixing/loading site or into potable water sources provide the potential for worst possible exposures to humans. Such accidents can result in direct or indirect exposure to the herbicide. Direct exposure results primarily from spray or liquid deposition on the skin or from immersion into the liquid. Indirect exposure results from the consumption of contaminated water supplies or food.

The impact of a spill or dump depends on many variables such as the spill source (truck, aircraft, or backpack), size of load, distance to water, stream size, and density of human and animal population. In developing the accident scenarios, worst-case assumptions were used on all critical parameters.

One hypothetical accident scenario involving a large truck spill into a drinking water reservoir is developed in this section. This accident would result in indirect human exposure through consumption of contaminated drinking water.

In order to bracket the impact of a spill of herbicide into a water reservoir, the possible impact on two different reservoirs was investigated. The first assumed a spill into a large reservoir which is a major source of drinking water for the town of Butte, Montana, population 35,000. A second spill was assumed in a small reservoir which was the sole source of drinking water for about 500 residents of a northern section of Bozeman, Montana.

The effects of a second type of worst-case accident involving an aircraft spill were also analyzed. In this scenario, a helicopter was assumed to jettison its load over workers at an application site. Direct exposure to the spilled herbicide would result in dermal absorption of the pesticide deposited on those at the spill site.

The second type of accident is not possible under current proposals for the Region 1 noxious weed program since the use of aircraft is not proposed. This accident scenario is provided for illustrative purposes only for other western regions that have considered aerial application.

Analyses were also made of various other types of vehicle and personal accidents. None of these other accident types would involve as great a potential for human exposure and dosage as the worst-case scenarios outlined above.

## 3.2 Truck Spills

### 3.2.1 Probability of Occurrence

Several sources were reviewed for information on frequency of accidents involving pesticides. Personal injury/illness reports and vehicle accident reports from Forest Service Region 1 for the years 1977-1985 were reviewed.

These records indicate that there were no accidents involving Region 1 Forest Service vehicles transporting any type of pesticide including herbicides for noxious weed control programs.

Calculation of the probability of a vehicle accident in which a major spill of herbicide is released in water or on land, is based on Department of Transportation (DOT) accident statistics for single-unit trucks, the type commonly used in noxious weed projects, as opposed to large tractor-trailer or tandem trucks.

According to the DOT Highway Statistics Division, single-unit trucks, the vehicles under consideration, traveled 353,978 million miles in 1981. National Accident Sampling System (NASS) statistics estimate that single-unit trucks were involved in 162,000 accidents that year, or one accident for 2,185,049 miles traveled (353,978 million miles/162,000 accidents). The mean probability of a single-unit truck accident can be calculated:

$$P_a = \frac{1}{2{,}185{,}049 \text{ miles per accident}} = 0.000000457 \text{ or } 4.6 \times 10^{-7}$$
accidents per mile

Where $P_a$ = the mean probability of a single-unit truck accident per mile.

The frequency of accidents differs according to road type. The mean probability of a single-unit truck accident can subsequently be adjusted to take road type into account. The following tabulation gives total miles traveled, number of accidents, and accident frequency (miles traveled per accident) for single-unit truck accidents for road type based upon 1981 data. The probability of an accident occurring per mile is the inverse of the accident frequency.

| | Single-unit truck | | Accident frequency (miles traveled per accident) | Probability of accident/mile |
|---|---|---|---|---|
| Road type | Total miles (million) | Number of accidents | | |
| Urban interstate | 23,059 | 13,449 | 1,714,551 | $5.8 \times 10^{-7}$ |
| Rural interstate | 28,758 | 958 | 30,018,789 | $3.3 \times 10^{-8}$ |
| Other urban roads | 146,195 | 92,430 | 1,581,683 | $6.3 \times 10^{-7}$ |
| Other rural roads | 155,966 | 55,163 | 2,827,366 | $3.5 \times 10^{-7}$ |

It is estimated that single-unit trucks used on noxious weed projects traveled all road types in these proportions:

Other urban roads - 10 percent.
Other rural roads - 90 percent.

By applying the accident probabilities for road type just generated to the proportions traveled during noxious weed projects, an adjusted probability of occurrence for single-unit truck accidents can be calculated as follows:

$$P_a = (0.10 \times 6.3 \times 10^{-7}) + (0.90 \times 3.5 \times 10^{-7}) = 0.000000378$$
$$3.8 \times 10^{-7} \text{ per mile}$$

Where $P_a$ = probability of an accident involving a single-unit truck occuring per mile traveled.

Not all accidents will result in the release of herbicide. In estimating the potential for herbicide release, accident severity must be taken into account. As noted earlier, accident estimates provided thus far include all accidents reported to authorities regardless of severity. In adjusting for probability of herbicide release, it is assumed that only those accidents severe enough to require towing of vehicles from the scene of an accident result in the release of herbicide.

The only data base available on the severity of accidents aggregates single and tandem trucks together although size of the load is categorized. For these vehicles, 68 percent were involved in collisions with other vehicles, 21 percent with fixed objects, and 10 percent were noncollision accidents. Towing was required in 20 percent of the multi-vehicle collisions, 60 percent of the collisions with fixed objects, and 100 percent of the turnovers and ruptures.

The probability of a truck accident resulting in herbicide release can be calculated for each accident type:

$$P = P_a \times A_t \times P_t$$

Where $P_a$ = Probability of an accident occurring per mile traveled $(3.8 \times 10^{-7})$

$A_t$ = Proportion of accidents by accident type (0.68, 0.21, and 0.10)

$P_t$ = Proportion of accidents by accident type that require towing (0.2, 0.6, and 1.0).

For example, for accidents that involve collision with another vehicle, this computes as:

$$P = (3.8 \times 10^{-7}) \times (0.68) \times (0.2) = 5.2 \times 10^{-8}$$

The probability of pesticide release for all accident types is summarized below:

| Accident type | Probability of release |
|---|---|
| Collision with vehicle | $p = 5.2 \times 10^{-8}$ |
| Collision with fixed object | $p = 4.8 \times 10^{-8}$ |
| Noncollision accident | $p = 3.8 \times 10^{-8}$ |
| TOTAL | $p = 1.4 \times 10^{-7}$ |

The probability of a truck accident releasing herbicide for all accident types is the sum of the individual probabilities or, $P = 1.4 \times 10^{-7}$ per mile traveled.

Assuming that a vehicle carrying herbicide travels an average of 40 miles during the course of a project for each of 1,000 projects in a year, the annual probability that a traffic accident would occur in which herbicide is spilled would be $1.4 \times 10^{-7}$ accidents/mile x 40 miles/project x 1,000 projects/year or $5.6 \times 10^{-3}$ accidents/year. Thus, on the average, about six accidents every 1,000 years might be expected to result in a spill of herbicides.

Generally most trucks carrying herbicide would be carrying small quantities (4 to 8 pounds active ingredient) to supply backpack spray projects. From a health effects perspective, the trucks carrying the largest quantities are the greatest concern. Trucks carrying large quantities of herbicide mixture (up to 1,140 liters or 300 gallons) are typically involved in spraying road rights-of-way. Assuming these trucks drive an average of 40 miles per project and for 30 of these miles they are loaded with herbicide (or conversely 10 miles empty and returning to reload), and assuming 100 projects per year, the probability of an accident resulting in a spill of herbicide from these larger trucks would be $4.2 \times 10^{-4}$ (30 miles/project x 100 projects/year x $1.4 \times 10^{-7}$ accidents/mile). This is equivalent to about one accident every 2,400 years.

### 3.2.2 Worst-Case Truck Spill

As demonstrated in the previous section, the probability of a major spill of herbicide is relatively small. Nonetheless, the small probability cannot be denied. It is, of course, impossible to predict the exact nature, effect, or frequency of such an occurrence. In order to place a boundary on the impact of accidents involving pesticides, an analysis of the worst-case type of accident was performed. If the risk to human health can be shown for such an accident, then it is reasonable to expect that the health effects from less catastrophic incidents should be less.

A worst-case truck spill is hypothesized to involve the rupture of a tank carrying 1,140 liters (300 gallons) of pesticide mixture containing 10 kilograms (22 pounds) of herbicide active ingredient.

It is assumed that the worst place to dump a large quantity of pesticide would be into a drinking water reservoir. A worst-case reservoir is assumed to be one in which a spill will result in the highest dose over time to the greatest number of people. The highest concentration for the longest period of time would occur in those reservoirs with small volumes and a long hydraulic residence time (i.e., low flow through the reservoir). These characteristics, however, tend to be mutually exclusive since low volume reservoirs will necessarily have higher throughput (short resident time).

In order to find the worst-case reservoir, data on all above-ground drinking water sources for cities and towns in the vicinity of Region 1 National Forest Lands were reviewed.

Two extreme cases were selected for further analysis. The first analysis assumed a herbicide spill into a large reservoir serving a large number of people. The second scenario assumed a spill into a smaller reservoir serving

fewer people. In the first case, larger numbers of people would be exposed to smaller concentrations because the large reservoir would provide substantial dilution. In the second scenario, the impact of higher dosage to smaller populations was analyzed.

In the first spill scenario it is assumed that 1,140 liters (300 gallons) of herbicide mixture containing 10 kilograms (22 pounds) of herbicide active ingredient is spilled directly into Basin Creek Reservoir. Basin Creek Reservoir provides 35 to 50 percent of drinking water for the City of Butte, Montana (population 35,000). Butte is typical of many mid-sized and larger towns in the West and all larger towns near Region 1 National Forests in that its drinking water is supplied by several sources. In addition to Basin Creek, Butte is supplied by water from the Big Hole River and to a lesser degree by a second smaller reservoir.

The city has the capacity to shut down one water source if problems develop. However, the analysis below presumes that the city would continue to pump from the contaminated reservoir.

The accident scenario assumes that herbicide is spilled directly into the reservoir and that the herbicide mixes and is available in a very short period for uptake at the water supply intake. It is also assumed that no biological degradation, hydrolysis, or chemical oxidation of the compound occurs and that the concentration is reduced only through dilution. The change in concentration over time from dilution by clean influent water can be simulated by the differential equation:

1. $$\frac{dH}{dt} = -\frac{QH}{V}$$

where: H = mass of herbicide in the reservoir (milligrams)
Q = low summer flow to reservoir (liters/day)
V = volume of the reservoir
t = time (days)

The solution for the equation (1) is:

2. $$H = A \exp\left(\frac{-Qt}{V}\right)$$

where A = H at initial conditions (t = 0)

Based on historical data provided by Butte Water Company officials and the U.S. Geologic Survey, the reservoir is assumed to be at a summer low volume of 760 x $10^6$ liters (200 x $10^6$ gallons) and receiving a summer low flow of 7.2 x $10^6$ liters per day (1.9 x $10^6$ gallons per day).

Using equation 2 it can be shown that from an initial concentration of 0.013 mg/liter, the concentration would fall to 0.005 mg/liter in 100 days if dilution were the only method of removal. Again, this is a very conservative assumption since photolytic oxidation, hydrolysis, biological degradation, and adsorption to sediments would also contribute to the reduction of the herbicide concentration.

Assuming that the water from Basin Creek is diluted 50 percent with water from other sources (typically it is diluted more than 50 percent), and assuming that the average 70 kg person consumes 2 liters of water per day, the dose of herbicide on the initial day would be 0.00019 mg/kg. This dose is below the acceptable daily intake (ADI) for all herbicides analyzed here. The dose is more than 50 times below the ADI for 2,4-D, which has the lowest ADI of the herbicides used in the past for noxious weed control in Region 1. Dosage on subsequent days would likewise be significantly below the NOEL threshold.

The impact of a worst-case accidental spill of the herbicides picloram, 2,4-D, glyphosate, and amitrole on cancer rates can also be calculated. To calculate dosage, it was assumed that the concentration would fall with dilution as outlined above for 270 days at which time high spring time runoff would completely flush the reservoir of the remaining low concentration, thus effectively ending exposure. Assuming only dilution, the concentration in the reservoir would fall to 0.001 mg/L by day 270.

In order to calculate the total dosage to consumers of the water over the 270-day exposure period, each day is treated as a separate exposure event. The mass of herbicide contained in the reservoir on each of the exposure days can be summed by integrating equation 2 between t = 0 and t = 270.

$$TH = A \int_{t=0}^{t=270} \exp\left(\frac{-Qt}{V}\right) = A \left| \frac{\exp\left(\frac{-Qt}{V}\right)}{\frac{-Q}{V}} \right|_{t=0}^{t=270}$$

Using this integral, the total mass of herbicide (TH) summed over the time frame would be $9.7 \times 10^{8}$ mg. The average daily concentration can be calculated as 0.0047 mg/L ($9.7 \times 10^{8}$ mg/270 days/$7.6 \times 10^{8}$ L). The average dose to the average individual (70 kg individual) over the 270 days (assuming 50 percent dilution of contaminated water) would be $6.7 \times 10^{-5}$ mg/kg (0.0047 mg/L x 2L x 0.5 x 1/70 kg).

As discussed in Section 2.7, the probability of cancer occurring to a person as a result of this exposure can be calculated using the equation:

$$Pc = q^* \times D \times De/L$$

where: Pc = worst-case estimate of the probability of cancer as a result of the dose

q* = the upper limit of the carcinogenic potency slope
($5.03 \times 10^{-3}$ per (mg/kg/day) for 2,4-D;
$5.68 \times 10^{-4}$ per (mg/kg/day) for picloram;
1.4 per (mg/kg/day) for amitrole); and
$3.4 \times 10^{-5}$ per (mg/kg/day) for glyphosate)

D = average daily dose in mg/kg/day

De = number of days during which the daily dose occurs

L = days in a lifetime (25,550).

Using this equation, the incremental probability of cancer in a lifetime from drinking contaminated water can be calculated.

For picloram the probability of cancer for an individual, given the worst-case accident scenario, is $4.0 \times 10^{-10}$ in a lifetime or four chances in 10 billion. For the entire town of Butte (population 35,000), the probability of an additional case of cancer over a 70-year period is $1.4 \times 10^{-5}$ ($35,000 \times 4.0 \times 10^{-10}$) or about one chance in 100,000.

For 2,4-D the probability of cancer for an individual, given the worst-case accident secnario, is $3.6 \times 10^{-9}$ in a lifetime (or about four chances in 1 billion). For the entire town of Butte, the probability of an additional case of cancer over a 70-year period is $1.2 \times 10^{-4}$ or about one chance in 10,000.

For glyphosate the probability of cancer for an individual is $2.4 \times 10^{-11}$ (or about three chances in 100 billion). For the entire town of Butte, the probability of an additional case of cancer is $8.4 \times 10^{-7}$, or about one chance in a million.

For amitrole the probability of cancer for an individual, given the worst-case accident scenario, is $1.1 \times 10^{-6}$ in a lifetime (or about one chance in a million). For the entire town of Butte, the probability of an additional case of cancer over a 70-year period is $3.6 \times 10^{-2}$ or about one chance in 25.

The impact of a major spill into a smaller reservoir can also be analyzed. Lyman Creek Reservoir serves as the sole source of drinking water for about 500 residents in the northern section of Bozeman, Montana. This reservoir has a capacity of $10 \times 10^6$ liters ($2.3 \times 10^6$ gallons) and has a low daily summer inflow of $3.8 \times 10^6$ liters ($1.0 \times 10^6$ gallons).

Using the same initial spill conditions and other assumptions presented above in the Basin Creek Reservoir example, it is possible to calculate the change in concentration over time. From an initial concentration of 0.5 milligrams per liter, the concentration falls to 0.07 mg/L in 10 days and 0.011 mg/L in 20 days. Based on a 2-liter per day consumption of water, the dose on the first day to a 70 kg person would be 0.014 mg/kg. This initial dose is below the ADI for atrazine, glyphosate, and picloram. Within 1 day the dose would be below the ADI for all herbicides except amitrole. Within about 10 days the dose would be below the amitrole ADI, assuming only dilution of the herbicide and no other reduction mechanisms.

In calculating the effects of such a spill, it is evident that the greatest impacts would occur from concentrations experienced in the first 40 days and that the incremental impacts after that would be insignificant in comparison. The concentrations in the reservoir on day 40 would be 0.00025 mg/L (from 0.5 mg/L on day 1). The total daily doses after day 40 could be expected to be less than 0.1 percent of the total daily doses up to that day. Thus a 40-day exposure period is used in determining cancer rates from possible exposure to picloram, 2,4-D, glyphosate, and amitrole.

As in the Basin Creek example, the total mass of herbicide over the 40 days was calculated from the integral:

$$TH = A \int_{t=0}^{t=40} \exp \frac{-Qt}{V} = A \left| \frac{\exp\left(\frac{-Qt}{V}\right)}{\frac{-Q}{V}} \right|_{t=0}^{t=40}$$

The total mass of herbicide (TH) integrated over the 40 days would be $5.2 \times 10^{7}$ mg. The average daily concentration would be 0.065 mg/L ($5.7 \times 10^{7}$ mg/40 days/$20 \times 10^{8}$ L). The average daily dose to a 70 kg person drinking 2.0 liters of water per day would be $1.9 \times 10^{-3}$ mg/kg (0.065 mg/L x 2 L x 1/70 kg).

As with the Butte example, the probability of cancer to an individual and to the entire population can be calculated. For picloram the probability of cancer for an individual given the worst-case accident scenario, is $1.6 \times 10^{-9}$ or about two chances in a billion. For the entire exposed population of northern Bozeman (500 people), the total probability of an additional case of cancer over the lifetime of all residents following the spill is $8.0 \times 10^{-7}$ ($500 \times 1.6 \times 10^{-9}$) or about one chance in a million.

For 2,4-D, the probability of cancer for an individual, given the worst-case accident scenario, is $1.5 \times 10^{-8}$ or about two chances in 100 million. For the entire exposed population of northern Bozeman (500 people), the probability of an additional case of cancer following the spill is $7.5 \times 10^{-6}$, or about one chance in 100 thousand.

For glyphosate, the probability of cancer for an individual, given the worst-case accident scenario is $1.0 \times 10^{-10}$ or about one chance in ten billion. For the entire exposed population, the probability of an additional case of cancer resulting from the spill is $5.1 \times 10^{-8}$ or about five chances in 100 million.

For amitrole the probability of cancer for an individual is $2.2 \times 10^{-6}$. For the entire exposed population of northern Bozeman, the probability of an additional case of cancer is $2.2 \times 10^{-3}$, or about two chances in a thousand.

In comparing the two hypothetical truck spills, it can be seen that higher probabilities of cancer occur to each individual in the hypothetical Bozeman example. However, because fewer people would be exposed in the Bozeman example, the total population effects are less than in the Butte example.

### 3.2.3 Probability of a Worst-Case Truck Spill

As might be expected, the probability of a worst-case truck spill is very small, the intersection of several rare events. As discussed in Section 3.2.1, trucks carrying large amounts of herbicide could be expected to be involved in an accident resulting in the spill of herbicides only once every 2,400 years.

The probability that a serious accident could impact a water supply system can be calculated by estimating the proportion of driving in the vicinity of water supply reservoirs. It was assumed that the 128 above-ground community water systems in Region 1 would each have approximately 25 miles of streamside road

upstream of the reservoir. This is an overestimate since many of these systems draw water from protected, unroaded or minimally roaded watersheds. Using the 25-mile estimate, indicates a total of 3,200 miles of road in the upstream vicinity of water supply systems. There are 37,000 miles of Region 1 Forest Service road and approximately 9,000 miles of State and county roads on the National Forests.

Assuming, conservatively, that all reservoirs and the roads above reservoirs are on National Forest System land, 7 percent of National Forest roads would thus be in the vicinity of reservoirs. Assuming that roads near reservoirs are driven with equal frequency as all other roads (a conservative assumption in Region 1 since many reservoirs are isolated and not accessible by heavily traveled thoroughfares), the probability of a serious truck accident on a road in the vicinity of a water supply system is thus reduced to one accident every 34,000 years (one major accident/2,400 years x 0.07). In addition, if the spill occurred on land, harm to persons served by the water supply would be further mitigated.

### 3.3 Worst-Case Aircraft Spill

This section presents data on possible impacts of spills from aircraft involved in aerial application of herbicides. It should be noted that the Forest Service has never aerially applied herbicides to control noxious weeds in Region 1 and has no plans to do so in the future. Indeed, in the past less than 50 acres a year have been aerially sprayed to control noxious weeds on all National Forests in western Regions.

No accidents have been reported with the limited aerial spray programs to control noxious weeds. In order to analyze the risks from aerial application programs, data from a Region 5 program involving extensive aerial application of herbicides for commercial timber site preparation will be used to estimate the probability of occurrence and potential impacts of accidents. Since this site preparation program often involves more severe terrain and operating conditions than the noxious weed programs, accident data from this program would be expected to conservatively indicate the probability and impact of aircraft accidents.

Several additional facts will be helpful to the reader in interpreting the possible impacts of aerial application programs. The analysis presumes application with helicopters (rather than fixed-wing aircraft) because of the small size of noxious weed control projects. An advantage to this application method is that the helicopter can be trucked to the application site with all herbicide mixing and loading occurring on site. Aerial transport is thus minimized, as is the probability of spills over non-target areas.

Reference will be made in the following section to the possibility of a helicopter jettisoning a load of herbicide. The Federal Aviation Administration requires that helicopters rigged for aerial applications have the capacity to jettison a full load of herbicide under emergency conditions. The jettison time for a typically equipped fully loaded helicopter is 3 seconds.

### 3.3.1 Probability of Occurrence

A review of herbicide aircraft incident records from Region 5 site preparation and release programs indicates that six total incidents involving aircraft occurred from 1976 through 1983. One incident involved a crash with the spillage of 150 gallons, a second incident involved a helicopter flying into a tree breaking a boom with no loss of pesticide, two incidents involved the jettison of material (250 gallons and 1 gallon) although there was no subsequent crash, and two incidents involved the overspray of streams.

Total acreage treated during those years was 148,000. Assuming 35 percent of these acres were aerially sprayed (or 51,800 acres) and 12 acres were treated per aerial load, then 4,320 individual aerial trips were required.

The probability of an aircraft incident per flight is 6/4,320 or $1.4 \times 10^{-3}$. The probability of occurrence of a major spill per flight is 2/4,320 or $4.6 \times 10^{-4}$.

An upper limit for the accident frequency ($\lambda_1$) can be calculated by a method described by Thedeen (1979) if the accidents are assumed to occur randomly in time. If N(a) is the number of accidents for up to "a" events (trips, miles driven, etc.), the upper confidence level with a $1-\alpha$ confidence limit is calculated as follows:

$$\lambda_1 = \frac{\chi^2_\alpha}{2a}$$

Where $\chi^2_\alpha$ is the standard chi square distribution found in statistical tables and summarized below for n equals 2(N(a)+1).

| | $2\lambda_1 a$ | | |
|---|---|---|---|
| n | = .500 | = 0.05 | = 0.01 |
| 2 | 1.39 | 5.99 | 9.2 |
| 4 | 3.36 | 9.49 | 13.3 |
| 6 | 5.35 | 12.6 | 16.8 |
| 8 | 7.34 | 15.5 | 20.1 |
| 10 | 9.34 | 18.3 | 23.2 |
| 12 | 11.3 | 21.0 | 26.2 |
| 14 | 13.3 | 23.7 | 29.1 |

For six accidents (N(a) = 6) in 4,320 aircraft loads, the value of $\chi^2_\alpha$ for the 95 confidence limit is 23.7 and the accident frequency, $\lambda_1$, is calculated:

$$\lambda_1 = 23.7/(2 \times 4{,}320)$$
$$= 2.7 \times 10^{-3}$$

For two major spills (N(a) = 2) in 4,320 aircraft loads, the value of $\chi^2_\alpha$ for the 95 confidence limit is 12.6 and the accident frequency, $\lambda_1$, is calculated:

$$\lambda_1 = 12.6/(2 \times 4{,}320)$$
$$= 1.5 \times 10^{-3}$$

Thus the upper limit on accident rates indicates that there is 1.5 chances out of a thousand that any helicopter spray trip would involve a major spill.

### 3.3.2 Worst-Case Aircraft Spill

The maximum aircraft load for the type of helicopter that would be used in the noxious weed control programs is 454 liters (120 gallons) of mixed herbicide. Each aerial load would cover from 4 to 5 hectares (10-12 acres). Assuming intended coverage of 4.5 hectares (11 acres) at 1.1 kg/ha (1 lb/ac), and mixing and formulation errors of 10 percent and 4 percent respectively, the helicopter would be carrying 5.7 kilograms (12.5 pounds) of herbicide active ingredient (4.5 x 1.1 kg/ha x 1.04 x 1.1).

At the time of the postulated jettison, the helicopter is presumed to be traveling at 48 kilometers/hour (30 miles/hour), and to drop its load over four workers involved in mixing/loading and supervision at the spray site. Based on a jettison time of 3 seconds and a speed of 48 km/hr (13.3 meters/second), the spill is presumed to cover an area 40 meters long (3 x 13.3) and 6 meters (20 feet) wide or 240 square meters.

Approximately 23.75 grams of herbicide would be deposited per square meter of spill area. Each worker is assumed to have 0.18 $m^2$ (2 $feet^2$) of uncovered skin exposed directly to the spill. The worker is also assumed to have 0.56 $m^2$ (6 $feet^2$) of clothing exposed to the spill. Twenty-five percent of the herbicide absorbed in clothing is assumed to contact the skin. As discussed in Section 2.4, dermal absorption rates of 1 percent for picloram and amitrole; 10 percent for dicamba, glyphosate, and 2,4-D; and 20 percent for hexazinone and atrazine.

The worst-case dose of glyphosate or 2,4-D would be 10.9 mg/kg (0.18 $m^2$ x 23,750 mg/$m^2$ x 0.1 x 1/70 kg) + (0.56 $m^2$ x 23,750 mg/$m^2$ x 0.25 x 0.1 x 1/70 kg). The doses of all other herbicides under these worst-case conditions are provided in Table 3.1. Cancer probabilities to a worker resulting from a one-time exposure to these doses are also provided in Table 3.1 for picloram, 2,4-D, and amitrole. The methodology outlined in Section 2.6 is used for these calculations.

The doses provided on Table 3.1 are above the NOEL values for chronic exposure for all herbicides except picloram. However, because this dose would be of short duration and because the effects from a dose level decrease with a decrease in exposure period, the effects from such a one-time worst-case dose would likely be slight to nonexistent.

### 3.3.3 Probability of Worst-Case Aerial Exposure

As demonstrated in Section 3.3.1, the probability of a major spill is 1.5 x $10^{-3}$ per flight. The probability that a major spill would directly expose workers cannot be calculated except to say that it is much smaller than the probability of an accident. The greatest possibility of exposure to people would occur in the vicinity of the loading zone during take off. All personnel typically evacuate this area during helicopter take-off and the helicopter flies from the area quickly.

Table 3.1--Worst-case doses and cancer probabilities from dermal exposure from an aerial spill.[1]

| | Dose (mg/kg) | Cancer probability |
|---|---|---|
| Picloram | 1.09 | $2.4 \times 10^{-7}$ |
| 2,4-D | 10.9 | $2.1 \times 10^{-6}$ |
| Glyphosate | 10.9 | $1.4 \times 10^{-8}$ |
| Dicamba | 10.9 | --- |
| Amitrole | 1.09 | $3.2 \times 10^{-5}$ |
| Atrazine | 21.7 | --- |
| Hexazinone | 21.7 | --- |

[1]Assumes 1.3 kg/ha (1.2 lb/ac) application rate and jettison of entire load directly onto bystander.

## 3.4 Other Accident Exposure Scenarios

Several other accidental exposure scenarios were examined as discussed below. In all cases, the exposure would result in human health impacts that are no more severe than those discussed under the worst-case accident scenarios.

In the event of a major truck accident and subsequent herbicide spills, there exists the possibility that the driver and cleanup workers could be directly exposed to herbicide. However, the exposure would be no greater than that detailed in the worst-case aerial spill directly over workers.

Worker exposure could result in the event of the spill of backpack application carrying 3 gallons of mixed herbicide. Direct exposure to a worker carrying the backpack would likewise be no greater than that presumed in the worst-case aerial spill.

The spill of 120 gallons of mixed herbicide from an aircraft into a drinking water reservoir would result in lower concentrations than that detailed in the worst-case truck spill since the aircraft would be carrying a smaller quantity of herbicide active ingredient.

## REFERENCES

Ames, B. N. 1983. Dietary carcinogens and anticarcinogens. Science 221: 1256-1264.

Ballantine, L. 1985. Letter and confidential enclosures submitted to E. Monnig May 24, 1985.

Baur, J. R. and R. W. Bovey. 1974. Ultraviolet and volatility loss of herbicdes. Arch. Environ. Contam. Toxicol. (2): 275-288.

Baur, J. R., R. W. Bovey, and M. G. Merkle. 1972. Concentration of picloram in runoff water. Weed Science. 20(4): 309-313.

Bouchard, D.C., T. L. Lavy, and E. R. Lawson. 1985. Mobility and persistence of hexazinone in a forest watershed. J. Environ. Quality. 14: 229-233.

Bovey, R. W., E. Burnett, C. Richardson, M. G. Merkle, J. R. Baur, and W. G. Knisel. 1974. Occurrence of 2,4,5-T and picloram in surface runoff water in the Blacklands of Texas. J. Environ. Quality 3: 61-64.

Bovey, R. W., E. Burnett, C. Richardson, M. G. Merkle, J. R. Baur, and W. G. Knisel. 1975. Occurrence of 2,4,5-T and picloram in subsurface water in the Blacklands of Texas. J. Environ. Qual. 4: 103-106.

Clark, D. E., J. S. Palmer, R. D. Radeleff, H. R. Crookshank, and F. M. Farr. 1975. Residues of chlorophenoxy acid herbicides and their phenolic metabolites in tissues of sheep and cattle. J. Agricul. Food Chem. 23: 573-578.

Crouch, E. A. C., and R. Wilson. 1982. Risk/benefit analysis. Ballinger. Cambridge, Massachusetts.

Crouch, E. A. C., R. Wilson, and L. Zeise. 1983. The risk of drinking water. Water Resources Res. 19: 1359-1375.

Davis, E. A. and P. A. Ingebo. 1973. Picloram movement from a chaparral watershed. Water Resour. Res. 9: 1304-1313.

Doull, J., C. D. Klaassen, and M. O. Amdur. 1980. Casarett and Doull's Toxicology, 2nd Ed., MacMillan Publishing Co., Inc. New York. 778 p.

Dow Chemical. Undated. Toxicology profile of Tordon herbicides. Publication No. 137-1640-1183. Agricul. Products Dept., Midland, Michigan.

Draper, W. H. and J. C. Street. 1982. Applicator exposure to 2,4-D, Dicamba and Dicamba isomer. J. Environ. Science Health. B17(4): 321-339.

Edwards, W. M., G.B. Triplett, Jr., and R. M. Kramer. 1980. A watershed study of glyphosate transport in runoff. J. Environ. Qual. 9 (4):661-665.

Fang, S. C., M. George, T. C. Yu. 1964. Metabolism of 3-amino-1,2,4-triazole-5-$c^{14}$ by rats. J. Agric. Food Chem. 12: 219-223.

Fang, S. C., S. Khanna and A. V. Rao. 1966. Further study on the metabolism of labeled 3-amino-1,2,4-triazole (ATA) and its plant metabolites in rats. J. Agric. Food Chem. 14: 262-265.

Feldman,R. J. and H. I Maibach. 1974. Percutaneous penetration of some pesticides and herbicides in man. Toxicol. and Appl. Pharm. 28: 126-132.

Fisher, D. E., L. E. St. John, W. H. Guttenmann, D. G. Wagner, and D. J. Lisk. 1965. Fate of Banvel T., Ioxynil, Tordon®, and Trifluoralin in the dairy cow. J. Dairy Sci. 48: 1711-1715.

Ghassemi, M., L. Fargo, P. Painter, P. Painter, S. Quinlivan, R. Scofield, and A. Takata. 1981. Environmental fates and impacts of major forest use pesticides. TRW, Redondo Beach, California.

Hansen, W. H., M. L. Quaife, R. T. Haberman, and O. G. Fitzhugh. 1971. Chronic toxicity of 2,4-dichlorophenoxyacetic acid in rats and dogs. Toxicol. and Pharmacol. 20: 122-129.

Hodge, H. C., E. A. Maynard, W. L. Downs, J. K. Ashton, and L. L. Salerno. 1966. Tests on mice for evaluating carcinogenicity. Toxicol. and Appl. Pharmac. 9: 583-596.

Hoerger, F. and E. F. Kenaga. 1972. Pesticide residues on plants: Correlation of representative data as a basis for estimation of their magnitude in the environment. In Environmental Quality and Safety. F. Coulston, ed. p. 9-28.

Howe, R. B. and K. S. Crump. 1982. Global 82: A computer program to extrapolate quantal animal toxicity data to low doses. Prepared for the Office of Carcinogen Standards, OSHA, U. S. Department of Labor, Contact 41USC252C3.

Innes, J. E., Innes, J. R. M., B. M. Ulland, M. G. Valenio, L. Patrucelli, L. Fishbein, E. R. Hart, A. J. Pallotta. 1969. Bioassay of pesticides and industrial chemicals for tumorigenicity in mice: A preliminary note. J. National Cancer Institute. 42: 1101-1114.

Jukes, T. H. and C. B. Shaffer. 1960. Anti-thyroid effects of aminotriazole. Science 132: 296-297.

Khan, S. U. and J. C. Young. 1977. N-nitrosamine formation in soil from the herbicide glyphosate. J. Agric. Food Chem. 25: 1430-1432.

Khan. S. U. and T. S. Foster. 1976. Residues of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and its metabolites in chicken tissues. J. Agric. Food Chem. 24 (4): 768-771.

Khanna, S. and S. C. Fang. 1966. Metabolism of $^{14}C$-labeled 2,4-D in rats. J. Agric. Food Chem. 14: 500-503.

Khera, K. S. and J. A. Ruddick. 1973. Polychlorodibenzo-p-dioxins: prenatal effects and dominant lethal test in Wisfor rats. Advances in Chemistry Series 120: chlorodioxins--origin and fate. E. H. Blair (ed.) American Chemical Society, Washington, D.C.

Kobayaski, S., S. Toida, H. Kawamora, H. Chang, T. Fukuda, and K. Kawaguchi. 1972. Chronic toxicity of 2,4-dichlorophenol in mice. J. of Agric. and Food Chem. 17: 283-287.

Kutschinski, A. H. and V. Riley. 1969. Residues in various tissues of steers fed 4-amino-3,5,6-trichloropicolinic acid. J. Agr. Food Chem. 17 (2): 283-287.

Lavy, T. L., J. S. Shepard, and J. D. Mattice. 1980. Exposure measurements of applicators spraying (2,4,5-trichlorophenoxy) acetic acid in the Forest. J. Agric. Food Chem. 28, 626-630.

Lavy T. L., J. D. Walstad, R. R. Flynn, and J. D. Mattice. 1982. (2,4-dichloro-phenoxy) acetic acid exposure received by aerial application crews during forest spray operations. J. Agric. Food Chem. 30 (2): 375-381.

Lavy T. L., J. D. Mattice, and L. A. Norris. 1984. Exposure of forestry applicators using formulations containing 2,4-D dichlorprop, or picloram in non-aerial applications. USDA Forest Service Completion Report for Project PNW-82-202, dated September 1984.

Levin, A., H. I. Maibach, and R. C. Wester. 1984. Assessment of dermal absorption of contaminants in drinking water. Prepared for USEPA, Office of Drinking Water, Washington, D.C. 20460. Yogi Patel, Project Director.

Marston, R. B., D. W. Schultz, T. Shiaoyama, and L. V. Snyder. 1968. Pesticides in water. Pesticides Monitoring J. 2: 123-128.

Maugh, T. H., II. 1978. Chemical carcinogens: How dangerous are low doses? Science 202: 37-41.

Maybank, J., K. Yosida, and S. R. Shewchuk. 1977. Spray drift and swath deposit pattern from agricultural pesticide application: Report of the 1976 field trial program. P-77-1. Saskatchewan Research Council. Saskatoon, Saskatchewan.

Mayeux, H. S., C. W. Richardson, R. W. Bovey, E. Burnett, M. G. Merkle, and R. E. Meyer. 1984. Dissipation of picloram in storm runoff. J. Environ. Qual. 13 (1): 44-49.

McCollister, D. D. and M. L. Leng. 1969. Toxicology of picloram and safety evaluation of Tordon herbicides. Down to Earth 25 (2): 5-10.

Mirvish, S. S. 1975. Formation of N-nitroso compounds: chemistry, kinetics, and in vivo occurrence. Toxicology and Applied Pharmacology. 31: 325-351.

Monsanto Company. 1982. Roundup$^{R}$ Herbicide Bulletin. No. 3, July. Monsanto Company, St. Louis, Missouri.

Monsanto Company. 1984. Roundup® herbicide information sheet: n-nitrosoglyphosate. St. Louis, Missouri.

Nash, R. G., P. C. Kearney, J. C. Maitlen, C. R. Sell, and S. N. Fertig. 1982. Agricultural applicators exposure to 2,4-dichlorophenoxyacetic acid, in Pesticide Residues and Exposure. J. R. Plimmer, ed. ACS Symposium Series 182. American Chem. Soc., Washington, D.C. pp. 119-132.

National Academy of Sciences - National Research Council. 1977. Drinking Water and Health, Vol. 1. Report of the Safe Drinking Water Committee, Washington, D. C. 939 p.

National Cancer Institute. 1978. Bioassay of picloram for possible carcinogenicity. DHEW publication no. (NIH) 78-823. Carcinogenesis Tech. Rept. Series No. 23, National Cancer Institutes of Health, Bethesda, Maryland.

National Cancer Institute. 1979. Bioassay of 2,7-dichlorobibenzo-p-dioxin for possible carcinogenicity. CAS No. 33857-26-0 NCI-CG-TR-123. Bethesda, Maryland.

National Research Council of Canada. 1974. Picloram: The effects of its use as a herbicide on environmental quality. National Research Council of Canada, Associate Committee on Scientific Criteria for Environmental Quality, Ottawa, Ontario, Canada.

Natural Resources Defense Council. 1984. Pesticides in Food. San Francisco, California.

Neary, D. G., P. B. Bush, J. E. Douglass, and R. L. Todd. 1985. Picloram movement in an Appalachian hardwood forest watershed. J. Environ. Qual. 14: 585-592.

Neary D. G., P. B. Bush, and J. E. Douglass. 1983. Off-site movement of hexazinone and storm flow and base flow from forest watersheds. Weed Science. 31: 543-551.

Newton, M., K. M. Howard, B. R. Kelpsas, R. Danhaus, C. M. Lottman, and S. Dubelman. 1984. Fate of glyphosate in an Oregon forest ecosystem. J. Agr. and Food chem. 32: 1144-1151.

Nolan, R. J., N. L. Freshour, P. E. Kastl, and J. H. Saunders. 1984. Pharmacokinetics of picloram in male volunteers. Toxicology and Applied Pharmacology. 76: 264-269.

Norris, L. A. 1981. The movement, persistence, and fate of the phenoxy herbicides and TCDD in the forest. Pesticide Reviews 80: 66-135.

Norris, L. A. 1968. Stream contamination by herbicides after fall rains on forest lands. Res. Prog. Report. West. Soc. Weed Sci.

Norris, L. A., M. L. Montgomery, L. E. Warren, and W. D. Mosher. 1982. Brush control with herbicides on a hill pasture site in southern Oregon. Jour. Range Mgmt. 35 (1): 75-80.

Oehler, D. D. and G. W. Ivie. 1980. Metabolic fate of the herbicide dicamba in a lactating cow. J. Agric. Food Chem. 28: 685-689.

Peterson, R. V. 1983. Letter to Rene Mangin November 16, 1983.

Redemann, C. T. 1963. The metabolism of 4-amino-3,5,6-trichloropicolinic acid by the dog. Unpublished report GS-609. The Dow Chemical Company, Seal Beach, California.

Roby, Douglas. December 21, 1984. Dow Chemical. Personal communication with E. C. Monnig.

Sacher, R. M. 1978. Safety of Roundup$^{R}$ in the aquatic environment. Proc. EWRS 5th Symp. on Aquatic Weeds. 5: 315-322.

Sanborn, J. R., B. M. Francis, and R. L. Metcalf. 1977. The degradation of selected pesticides in soil: A review of the published literature. EPA-600/9-77-022. Environmental Protection Agency. Cincinnati, Ohio.

Saunders, S. 1985. U.S. Environmental Protection Agency. Personal Communication with E. Monnig. July 22.

Schneider, P. W., Jr., and A. M. Kaplan. 1983. DuPont, Haskell Laboratory Report Toxicological Information on Hexazinone. October 12, 1983.

Schwab, G. O., E. O. McLean, A. C. Waldron, R. K. White, and D. W. Michener. 1973. Quality of drainage water from a heavy textured soil. Trans Amer. Soc. Agr. Eng. 16: 1104-1107.

Selikoff, I. J., E. C. Hammond, and J. Churg. 1986. Asbestos exposure, smoking, and neoplasia. J. Am. Med. Assoc. 204: 106-112.

Spencer, H. 1985. U. S. Environmental Protection Agency. Personal Communication with Edward Monnig, May 3.

Statham, C. N. and J. J. Lech. 1975a. Potentiation of the acute toxicity of several pesticides and herbicides in trout by carbaryl. Toxicol. Appl. Pharmacol. 34: 83-97.

Statham, C. N. and J. J. Lech. 1975b. Synergism of the acute toxic effects of 2,4-D butyl ester, dieldrin, rotenone, and pentachlorophenol in rainbow trout by carbaryl. Toxicol. Appl. Pharmacol. 33: 188.

Thedeen, T. 1979. The problem of quantification in energy risk management. Rowe and Goudmen (ed.) Academic Press, London.

Thompson, D. G., G. R. Stephenson, and M. K. Sears. 1983. Persistence, distribution and dislodgability of 2,4-D following application to turf grass. Paper presented at National Weed Society Meeting; St. Louis, Missouri.

Trichell, D. W., H. L. Morton, and M. G. Merkle. 1968. Loss of herbicides in runoff water. Weed Sci. 16: 447-449.

Tsuda, H., M. Hananouchi and M. Tatematsu. 1976. Tumorigenic effect of 3-amino-1H-1,2,4-triazole and rat thyroid. J. Natl. Cancer Inst. 57: 861-864.

U. S. Department of Agriculture. 1981. Herbicide background statements. Pacific Northwest Region, Forest Service, Portland, Oregon.

U. S. Department of Agriculture. 1984. Pesticide Background statements, Volume 1: Herbicides. Agriculture Handbook No. 633.

U. S. Environmental Protection Agency. 1981. Atrazine; proposed tolerance. Federal Register 46 (250) December 30, 1981. p. 63085.

U. S. Environmental Protection Agency. 1982a. P. R. Notice 82-1 Changed policy on tank mix compatibility. EPA Office of Pesticide Programs. January 12, 1982. Washington, D.C.

U. S. Environmental Protection Agency. 1982b. Tolerance and exemptions; 2,4-D. Federal Register 47 (227). November 24, 1982. p. 53060.

U. S. Environmental Protection Agency. 1983a. Tolerance and exemptions; dicamba. Federal Register 48 (52). March 16, 1983. p. 11119.

U. S. Environmental Protection Agency. 1983b. Hexazinone; tolerances and exemptions. Federal Register 48 (160). August 17, 1983. p. 37214.

U. S. Environmental Protection Agency. 1984a. Data requirements for pesticide registration; final rule. Federal Register 49 (207): 42856-42905.

U. S. Environmental Protection Agency. 1984b. Proposed guidelines for mutagenicity risk assessment; request for comments. Federal Register 49 (227): 46314-46321.

U. S. Environmental Protection Agency. 1984c. Guidance for the reregistration of the pesticide products containing carbaryl as the active ingredient. EPA Office of Pesticide Programs, Washington, D.C.

U. S. Environmental Protection Agency. 1985a. Memo and enclosures from Margaret Schneider, Office of Federal Activities, USEPA to Charles Sherman, Cannabis Investigation, Drug Enforcement Administration. October 3, 1985.

U. S. Environmental Protection Agency. 1985b. Memo and enclosures from Steven Schatzow, Director of the Office of Pesticide Programs to Allan Hirsh, Director of the Office of Federal Affairs, August 7, 1985. This document is available from EPA through a Freedom of Information Act request.

U. S. Environmental Protection Agency. 1985c. Risk assessment on amitrole. Memo from C. Gregorio and B. Litt, HED to L. Rossi, Registration Division. USEPA. Washington, D.C. This document is available from EPA through a Freedom of Information Act request.

U. S. Environmental Protection Agency. 1985d. Pesticide tolerances for glyphosate. Federal Register 50(210). October 30, 1985. pp 45121-45123.

Vershueren, K. 1983. Handbook of environmental data on organic chemicals. Van Nostrand Reinhold Co., New York.

Yates, W. E., N. B. Akesson, and D. E. Bayer. 1978. Drift of glyphosate sprays applied with aerial and ground equipment. Weed Science 26 (6): 597-604.

# APPENDIX A

## Glossary

### A

Acceptable Daily Intake (ADI). The maximum dose of a substance that is anticipated to be without lifetime risk to humans when taken daily.

Acetone. A colorless, volatile liquid that is useful as a solvent. It is found in the blood and urine when fats are not properly metabolized.

Acid Equivalent (a.e.). The amount of active ingredient expressed in terms of the parent acid.

Active Ingredient (a.i.). The chemical in a herbicide that is primarily responsible for its phytotoxic or herbicidal action.

Acute Toxicity. The quality or potential of a substance to cause injury or illness shortly after exposure to a relatively large dose.

Adenoma. An abnormal growth of glandular tissue.

Adenocarcinomatous. Referring to a malignant (cancerous) adenoma.

Adsorption. Adhesion of substances to the surfaces of solids or liquids. Technically, the attraction of ions of compounds to the surfaces of solids or liquids.

Ames Assay. A type of short-term test using bacteria in laboratory cultures to assess the mutagenic potential of a substance.

Amino Acid. Any of a group of carbon compounds containing one or more amino groups combined with one or more carboxyl groups. This class of compounds form the building blocks of proteins.

Antidote. A substance used to counteract or alleviate the effects of a poison. A practical treatment, including first aid, used in treatment of poisoning; e.g., atropine in organophosphorus or carbamate poisoning.

Assay. A test or measurement used to evaluate a characteristic of a chemical. See Bioassay.

### B

Bacteriophage. A group of transmissable agents (bacterial viruses) capable of destroying certain bacterial cells.

Bile Ducts. Passages that convey the bile from the liver to the gall bladder to the small intestine.

Bioaccumulation. The process of a plant or animal selectively taking in or storing a persistent substance. Over a period of time, a higher concentration of the substance is found in the organism than in the organism's environment.

Bioassay. Determine of chemical effects in tests of living organisms. Also a method for quantitatively determining the concentration of a substance by its effect on a suitable animal, plant, or microorganism under controlled conditions.

Boom (herbicide spray). A tubular metal device that conducts an herbicide mixture from a tank to a series of spray nozzles. It may be mounted beneath a helicopter or a fixed-wing aircraft or behind a tractor.

Buffer Strip/Zone. A strip of vegetation that is left or managed to reduce the impact that a treatment or action on one area would have on another area.

## C

Carcinogenic. Capable of producing or inciting cancer.

Carcinoma. A malignant or cancerous tumor.

Certified Applicator. Commercial or private person qualified to apply restricted-use pesticides as defined by the EPA. Certification administered by each State (Department of Agriculture).

Chelating Agent. Certain organic chemicals i.e., ethylenediaminetetracetic acid) that combine with metal to form soluble chelates and prevent conversion to insoluble compounds.

Chemical Degradation. The breakdown of a chemical substance into simpler components through chemical reactions.

Cholangiofibrosis. An abnormal formation of fibrous tissue within the bile duct of the gall bladder.

Chromosome. Microscopic structures within the cell that are composed of DNA and the genes (hereditary determiners).

Chronic (effects or toxicity). Having poisonous or deleterious effects from prolonged exposure or repeated administration of a chemical.

Conifer. An order of the Gymnaspermae, comprising a wide range of trees, mostly evergreens that bear cones and have needle-shaped or scalelike leaves; timber commercially identified as softwood.

Crossing Over. The breaking and exchanging of parts of chromosomes between chromosome pairs during cell division.

Cytogenetic. Refers to the structure or function of chromosomes within cells.

D

Degradation. See chemical degradation.

Dermal Exposure. That portion of an amount of toxic substance comes into contact with the organism's body surface.

Dermal Toxicity. Toxicity of a material as tested on the skin, usually on the shaved belly of a rabbit; the property of a pesticide to poison an animal or human when absorbed through the skin.

Dislodgeable Residue. A pesticide residue that can be removed from surfaces such as foliage by physical contact.

DNA. Deoxyribonucleic acid. Any of various nucleic acids that are the molecular basis of heredity in many organisms.

Dominant Lethal Assay. A toxicity test whereby a male animal (usually a rodent) is exposed to a chemical substance and later sequentially mated with two female animals. The females are sacrificed, and the number and status of the fetuses is recorded.

Dose. The amount of chemical administered or received by an organism, generally at a given point in time.

Drift. That portion of a sprayed chemical that is moved by wind off a target site.

E

Ecosystem. An interacting system of organisms considered together with their environment; for example, marsh, watershed, and lake ecosystems.

Emulsifier: Surface active substance used to stabilize suspensions of one liquid in another, for example, oil in water. The chemical is partly hydrophilic and partly lipophilic.

Emulsion. A mixture in which one liquid is suspended as minute globules within another liquid, e.g. oil in water. An important component is the emulsifier, a surface active agent which is partly hydrophilic and partly lipophilic.

Environmental Impact Statement (EIS). A formal document to be filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a major Federal action.

E. coli or Escherichia coli. A common species of bacteria used in areas of biological research, including mutagenicity testing.

Ester. A compound formed by the reaction of an acid and an alcohol, generally accompanied by the elimination of water.

Exposure Analysis. The estimation of the amount of chemical that is in an organism's environment and available for uptake into the body.

F

$F_0$. In genetics and reproduction studies, the term indicates the first parents' generation.

$F_1$. In genetics, the term indicates the first generation of offspring from the $F_0$ generation.

Fate. The course of an herbicide in an ecosystem or biological system after it has been applied; including metabolism, microbial degradation, leaching, and photodecomposition.

Fetotoxic. Capable of producing adverse effects in a developing fetus.

Fibroblast. Any cell from which connective tissue is developed.

Formulation. A chemical mixture that includes a certain percentage of active ingredient (technical chemical) with an inert carrier.

Gavage. Feeding by way of a tube inserted into the stomach.

Gene. The basic unit of heredity. Each gene occupies a specific place (locus) on a chromosome.

Genotoxic. Harmful to genetic material (DNA).

Germ Cell. A functional sex cell that combines with the opposite sex cell for fertilization, for example, sperm, egg.

Global 82. A computer program by Howe and Crump (1982) used to fit the multistage or one-hit models to experimental cancer data.

H

Half-life. The amount of time required for half of a compound to degrade.

Hazard Analysis. The determination of whether a particular chemical is or is not causally linked to particular harmful effects.

HDT. Highest dose tested.

Hectare (ha). 10,000 square meters, or approximately 2.47 acres.

HeLa Cell Line. A human cell line originally derived from cancerous breast cells taken from a woman named Helen Lane.

Hemoglobin. The iron-containing compound in red blood cells that functions to carry oxygen from the lungs to the tissues.

Hepatoma. A tumor of the liver.

Herbaceous. A plant that does not develop persistent woody tissue above the ground.

Herbicide. A chemical used to control, suppress, or kill plants, or to severely interrupt their normal growth processes.

Heritable. Capable of being passed on from parents to offspring.

Histology. The study of the microscopic structure of tissue.

Histopathologic. Referring to tissue changes characteristic of disease.

Hydrolysis. Decomposition or alteration of a chemical substance by water.

Hyperplasia. An excessive proliferation of normal cells in the tissue of an organ.

Hypertrophy. An increase in size of an organ or structure that does not involve tumor formation.

Hypohatchet. A tool used to inject herbicide into a tree trunk or woody stem.

I

Inert ingredient. Ingredients in a product that do not contribute to the activity of the active ingredient. Examples: sand, clays, talc, diatomaceous earth, or liquid diluents considered to be inactive.

In Vitro. Pertaining to a test that is conducted outside the living body and in an artificial environment such as a test tube or petri dish.

In Vivo. Pertaining to a test that is performed within the living body of the organism.

Intraperitoneal. Related to a structure or process occurring within the peritoneum, a membranous lining of the body cavity.

Intravenous. Within or into a vein.

## K

Kilogram (kg). One thousand grams; or approximately 2.2 pounds.

## L

Label. All printed material on or attached to a pesticide container as required by law.

Latency Period. The time between a stimulus and its response.

$LC_{50}$. A lethal concentration rate at which 50 percent of the test animals will be killed. It is usually used in the testing of fish or other aquatic animals.

$LD_{50}$. The dosage of toxicant, expressed in milligrams of toxicant per kilogram of animal body weight, required to kill 50 percent of the animals in a test population when given orally.

LDT. Lowest dose tested.

Leach. Usually refers to the movement of chemicals through soil by water; may also refer to the movement of herbicides out of leaves, stems, or roots into the air or soil.

Least Squares Estimation. A mathematical approach used to fit a straight line (or other models) so that the sum of the squares of the vertical distances of the data points from the line will be a minimum.

Lowest Effect Level (LEL). The lowest dose tested that results in an effect in a test organism.

Linear Regression. A mathematical procedure used to draw a straight line that best fits a set of data points on a graph.

Log-Probit Model. An equation used to describe the relationship between dose and the probability of contracting cancer. This equation can be derived by assuming that humans (or animals) have various susceptibilities, but that at very low doses none has a significant risk.

Lymphocyte. A cell of the lymphatic system, or a special type of white blood cell.

Lymphoma. A general term for the growth of new tissue in the lymphatic system.

## M

Malignant. Used in reference to a tumor; indicating the presence of cancer and tending to grow worse and spread within an organism.

Margin of Safety (MOS). The ratio between the no-observed-effect level (NOEL) and the estimated dose.

Metabolism. The chemical changes in living cells by which energy is provided for vital processes and new material is assimilated.

Metabolite. A product of the chemical changes in living cells that provide energy and assimilate new material.

Microbial Degradation. The breakdown of a chemical substance into simpler components by bacteria or other microorganisms.

Microgram (ug). One millionth of a gram.

Milligram (mg). One thousandth of a gram.

Mitigation Measures. Means taken to avoid, compensate for, rectify, or reduce the potential adverse impacts of a proposed action.

Mitotic. Pertaining to the process of cell division that results in two cells having the same number of chromosomes as the original cell.

Multistage Model. An equation used to describe the relationship between dose and the probability of contracting cancer. This equation, commonly used by EPA, assumes that several successive events must occur to produce cancer.

Mutagen. A substance that tends to increase the frequency or extent of genetic mutations (changes in hereditary material).

Mutagenic. Capable of producing genetic defects in an organism.

## N

Necrosis. Death of a cell or group of cells as a result of injury, disease, or other pathologic state.

Neoplastic. Pertaining to new abnormal tissue formation (neoplasms).

Neuropathy. Any disease or disability affecting neurons, the fundamental functional units of nervous tissues.

NOEL (no-observed-effect level). The highest dose level at which no toxic effects are observed in a test organism.

Noxious Weed. A plant regulated or identified by law as being undesirable, troublesome, and difficult to control.

Nucleic Acid. A group of complex molecules found in cells, composed of phosphoric acid, sugars, and nitrogen bases. Includes DNA and RNA.

## O

ODT. Only dose tested.

Omphalocele. A congenital hernia of the navel.

Oncogenic. Capable of producing or inducing tumors in animals, either benign (noncancerous) or malignant (cancerous).

Oncology. The branch of medicine which studies tumors.

One-Hit Model. An equation used to describe the relationship between dose and the probability of contracting cancer. This equation, used at one time by EPA, predicts the greatest cancer probability at low doses of all commonly used models.

Organic Material. An accumulation of decayed and resynthesized plant and animal residues with a high capacity for holding water and nutrients.

Ossification. The formation of bone.

## P

Papillary. Resembling or composed of small protuberances or elevations.

Parenteral. Injection of a substance into the body through any route other than the digestive tract.

Particulates. Finely divided solid or liquid particles in the air or in an emission; includes dust, smoke, fumes, mist, spray, and fog.

Pathology. The study of the nature and cause of disease with respect to functional and structural changes.

Persistence. The resistance of a pesticide to metabolism and environmental degradation.

Pesticide. As defined by FIFRA, any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

Photochemically Reactive. A property of substances or particles whose structures may be changed when solar energy is absorbed.

Photolysis (photodecomposition). The breakdown of a substance, especially a chemical compound, into simpler components by the action of radiant energy such as sunlight.

Photosynthesis. Formation of carbohydrates in the tissues of plants exposed to light.

Phytotoxic. Injurious or lethal to plants.

Pituitary Gland. A small, oval endocrine gland attached by a stalk to the base of the brain and consisting of an anterior and a posterior lobe; it secretes hormones that influence body growth, metabolism, and so forth (= hypophysis).

Potentiation. A term used to describe the enhanced toxicity attained by combining two or more toxicants giving more killing power than the sum of the individual toxicities. Used primarily in pharmacology, synergism being commonly used in insect toxicology.

ppm (parts per million). A unit for measuring the concentration of a substance, such as a pesticide, in a carrier medium, such as food or water. For example, where the concentration is 1 ppm, the weight of the substance is 1 millionth the weight of the carrier medium; thus 1 ppm is equal to 1 milligram of substance per kilogram of food or organism body weight, and it is effectively equal to 1 milligram of substance per liter of water.

Proliferation. The rapid and repeated reproduction of new cells.

Pulmonary. Concerning or involving the lungs.

Pyrolysis. Chemical breakdown caused in the process of combustion.

## R

Recreation Visitor Day (RVD). Twelve visitor hours, which may be aggregated continuously, intermittently, or simultaneously for one or more persons.

Reentry. The return of a worker or visitor to an area that has recently been treated with a pesticide.

Renal Tubule. The functional unit of the kidney where urine is formed (=nephron).

Residue. The quantity of a herbicide or its metabolites remaining in or on soil, water, plants, animals, or surfaces.

Resorption. Act of removal by absorption.

Risk Analysis. The description of the nature and often the magnitude of risk to organisms, including attendant uncertainty.

Runoff. That part of precipitation, that appears in surface streams, either perennial or intermittent, shortly after the precipitation event.

## S

Safety Factor. A factor conventionally used to extrapolate human tolerances for chemical agents from no-observed-effect levels in animal test data.

Salmonella. A genus of bacteria used in mutagenicity testing.

Sediment. Organic matter or soil that settles to the bottom of a liquid.

Shrub. A plant with persistent woody stems and relatively low growth form; usually produces several basal shoots as opposed to a single bole; differs from a tree by its low stature and nonarborescent form.

Silviculture. The branch of forestry dealing with the care, development, and reproduction of forest trees or stand of timber.

Sister Chromatid Exchange. A short-term test conducted with laboratory cell cultures to assess the genetic damage caused by a chemical or physical influence.

Solubility. An expression of the degree to which compounds dissolve in solvents.

Solvent. A liquid that will dissolve a substance forming a true solution (liquid in molecular dispersion). As applicable to pesticide toxicology, a liquid in which a pesticide will dissolve or be taken up.

Spot Treatment. Application of a herbicide to a small selected area as opposed to broadcast application.

Subchronic. The effects observed from doses that are of intermediate duration, usually 3 months (90 days).

Subcutaneous. Beneath the skin, or to be introduced beneath the skin.

Surfactant. A material that improves the emulsifying, dispersing, spreading, wetting, or other surface-modifying properties of liquids.

Synergism. The effect produced by two chemicals applied jointly where the total response is greater than the sum of their independent effects.

Systemic Herbicide. An herbicide that is moved within the plant. In a more restricted sense, refers to herbicides that are applied to the foliage and move downward through the living tissue to underground parts.

Systemic Toxicity. Effects produced as a result of the distribution of a poison or foreign substance from the point of exposure to a distant site within the body.

## T

$T_3$. Triiodothyronine. A chemical measured in tests which evaluate the functioning of the thyroid gland.

$T_4$. Tetraiodothyronine. A chemical measured in tests which evaluate the functioning of the thyroid gland.

Teratogen. A substance tending to cause irreversible developmental malformations in unborn human or animal offspring.

Teratogenesis. The irreversible development of abnormal structures in an embryo.

Teratogenic. Capable of producing or inciting the development of malformations in an embryo.

Teratology. The study of malformations in organisms.

Thiourea. A colorless crystalling form of urea containing sulfur in place of oxygen.

Thymus. A relatively small organ located in the upper chest that is important in the development of the immune system in newborn and young animals.

Thyroid Gland. A large, ductless gland lying in front of an on either side of the trachea and secreting thyroxine which regulates the growth of the body.

Thyroid Stimulating Hormone (TSH). A chemical secreted by the pituitary gland intended to cause the thyroid gland to produce its hormones.

Tolerance. In toxicological terminology, the relation of the magnitude of pesticide residues to standardized allowable amounts on foodstuffs. By law, a regulation that establishes the maximum amount of a pesticide chemical that may remain on the raw agricultural commodity. Expressed as parts per million (ppm).

Toxicity. A characteristic of a substance that makes it poisonous.

Toxicology. The science dealing with the study of the adverse biological effects of chemicals.

Tumor. A new growth of tissue that forms an abnormal mass and performs no physiologic function. It usually develops independent of and unrestrained by the normal principles of biological growth.

Tumorigenesis. The formation and/or develpment of a tumor (oncogenesis).

## V

Volatility. The quality of evaporating readily at normal temperatures and pressures.

Volatilization. The vaporizing or evaporating of a chemical substance.

## W

Wetting Agent. A material that insures direct contact between a solid and a liquid so that no layer of air exists between the two substances. Permits liquid mixture to more uniformly cover a waxy surface such as a leaf of a plant.

Wettable Powder (WP). A finely divided dry formulation that can be readily suspended in water.

# APPENDIX B

## Scientific Notation

$0.0000023 = 2.3 \times 10^{-6}$

$0.000023 = 2.3 \times 10^{-5}$

$0.00023 = 2.3 \times 10^{-4}$

$0.0023 = 2.3 \times 10^{-3}$

$0.023 = 2.3 \times 10^{-2}$

$0.23 = 2.3 \times 10^{-1}$

$2.3 = 2.3 \times 10^{0}$

$23 = 2.3 \times 10^{1}$

$230 = 2.3 \times 10^{2}$

$2,300 = 2.3 \times 10^{3}$

$23,000 = 2.3 \times 10^{4}$